INSTITUTE NOTES.

JANUARY 1939.

FORTHCOMING MEETINGS.

Tuesday, 14th February, 1939, at 5.30 p.m., at the Royal Society of Arts, John Street, London, W.C. 2. **"Some Factors in Oil Accumulation,"** by Professor V. C. Illing, M.A., M.Inst.M.M.

Tuesday, 14th March, 1939, at 5.30 p.m. at the Royal Society of Arts, John Street, London, W.C. 2. **Symposium on "Dangerous Gases in the Petroleum and Allied Industries."**

PRELIMINARY ANNOUNCEMENT.

22nd–24th May, 1939. The Summer Meeting of the Institute will be held at Birmingham. The programme of the meeting will be published in February.

NORTHERN BRANCH.

Thursday, 9th February, 1939, at 7.15 p.m., at the Engineers' Club, Albert Square, Manchester. Joint Meeting with the Institute of Chemistry. **"What Happens to Motor Oil and What Happens to the Engines,"** by C. I. Kelly, M.Sc., F.I.C., F.C.S.

Thursday, 16th February, 1939. **Annual Dinner and Dance** at the Midland Hotel, Manchester.

Thursday, 9th March, 1939, at the Engineers' Club, Albert Square, Manchester. **Annual General Meeting** and **"The Search for Oil in Britain,"** by G. W. Lepper, B.Sc., A.R.C.S.

Mr. Lepper's Lecture was originally delivered at the Conversazione held in London on 8th November, 1938. The Council subsequently invited Mr. Lepper to read his Lecture at each of the Institute's Branches in Great Britain.

Arrangements are also being made for the Lecture to be delivered to the Scottish Branch and at the University of Birmingham.

SCOTTISH BRANCH.

Friday, 24th March, 1939. **"The Planning of a Modern Colliery,"** by William Reid, B.Sc. Full particulars can be obtained from Prof. W. M. Cumming, D.Sc., Royal Technical College, Glasgow.

SOUTH WALES BRANCH.

Friday, 27th January, 1939, at 6.30 p.m., at the Hotel Metropole, Swansea. **"The Search for Oil in Great Britain,"** by G. W. Lepper, B.Sc., A.R.C.S.

STUDENTS' SECTION (LONDON BRANCH).

Wednesday, February 15th, at 5.45 p.m. at the Offices of the Institute, The Adelphi, London, W.C.2. **"Some Information on the use of Ethyl in Fuels for Automobile and Aviation Engines,"** by F. R. Banks, O.B.E., F.R.Ae.S., M.I.A.E.

Thursday, 16th March, at 5.45 p.m. at the Offices of the Institute, The Adelphi, London, W.C.2. **"The Application of Science to the Petroleum Industry,"** by G. H. Coxon.

TRANSFERS TO NEW CLASSES OF MEMBERSHIP.

The Temporary Regulations relating to the transfer of the existing members to the new classes of membership, as set out in the leaflet sent to all members of the Institute, were approved at the Special General Meeting held on 10th January, 1939.

Members who wish to transfer to one of the new classes of membership are requested to submit their applications as early as possible on the forms provided for the purpose at the back of the leaflet convening the Special General Meeting.

NEW MEMBERS.

The following elections were made by the Council in accordance with the By-Laws, Section IV, Para. 7 at the Council Meeting held on Tuesday, 10th January, 1939.

Elections are subject to confirmation in accordance with the By-Laws, Section IV, paras. 9 and 10.

Members.

Braune, Bernard	Germany.
Collins, William Thomas	Manchester.
Farrant, Victor Matthew	Manchester.
Frank, Fritz	London.
Ivanoff, Alexander	Luton.
Levi, Richard	Manchester.
Nicholson, Ian Howard Grant	South Africa.
Unmack, Edward West	Manchester.

Associate Members.

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Hilton, Charles James	Trinidad.

Students.

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McCue, Cyril Frederick	London.
Steel, George Reginald	Haywards Heath.

CANDIDATES FOR ADMISSION.

The following have applied for admission to the Institute or transfer to another grade of membership, and in accordance with the By-Laws the proposals will not be considered until the lapse of at least one month subsequent to the issue of this *Journal*, during which time any Member or Associate Member may communicate by letter to the Secretary, for the confidential information of the Council, any particulars he may possess respecting the qualifications or suitability of any candidate.

The object of this information is to assist the Council in grading candidates according to the class of membership.

The names of the candidate's proposer and seconder are given in parentheses.

Blane, Edward Richardson, Chemist (*Vacuum Oil Company*), "The Cottage," Lynwood Drive, Worcester Park, Surrey. (*S. J. M. Auld ; W. G. Gullick.*)

Braybrook, Frederick Houghton, Chemist (*Asiatic Petroleum Co.*), 57, Stanhope Gardens, London, S.W. 7. (*J. Kewley ; W. W. Goulson.*)

Bruce, Patrick David, Student, Imperial College Hostel, South Kensington, S.W. 7. (*V. C. Illing.*)

Chastelain, Alfred George Gardyne de, Engineer (*Unirea S.A.R. de Petrol*), Strada General Berthelot 90, Bucharest, Roumania. (*E. C. Masterson ; G. Elias*). (*Transfer from A. M.*)

Clarke, Geoffrey Jardine, Student, 10, Gunterstone Road, West Kensington, W. 14. (*V. C. Illing.*)

Eves, Hubert Bryan Heath, Director (*Anglo-Iranian Oil Co., Ltd.*), 4, Hampstead Hill Gardens, London, N.W. 3. (*S. J. M. Auld ; A. E. Dunstan.*)

Everett, Eric George, Student, 118, Shelbourne Road, Tottenham, N. 17. (*V. C. Illing.*)

Godber, Frederick, Director (*Asiatic Petroleum Co.*), St. Helens Court, Great St. Helens, London, E.C. 3. (*J. Kewley ; S. J. M. Auld.*)

Hanforth, William Percival, Engineer, c/o Asiatic Petroleum Co., Ltd., S.S., Ltd., Singapore. (*L. H. Cooper ; D. R. Howgill.*)

Hannah, Edwin George, Chemist (*British Bitumen Refineries Ltd.*), 14, Waverley Gardens, N. Stifford, Grays, Essex. (*E. Lawson Lomax ; C. E. Evans.*)

Heseltine, Guy Robert Nelson, Sales Manager, c/o Vacuum Oil Company, Ltd., Caxton House East, Westminster, S.W. 1. (*S. J. M. Auld ; W. G. Gullick.*)

Horne, Donald, Chemist (*Low-Temperature Carbonization Distillates, Ltd.*), 28, Oxcroft Lane, Bolsover, Nr. Chesterfield. (*G. S. Pound ; R. V. Wheeler.*)

KESSLER, Jean Baptiste, Director, Asiatic Petroleum Co., Ltd., St. Helens Court, Great St. Helens, London, E.C. 3. (*J. Kewley; S. J. M. Auld.*)
LEACH, Ronald Francis, Clerk (*Shell-Mex & B.P., Ltd.*), 2, Scott's Way, Sunbury-on-Thames, Middx. (*F. N. Harrap; W. B. Rowntree.*)
MARSHALL, Thomas Moye Berry, Chemist (*Shell Marketing Co., Ltd.*), 3, Marloes Road, London, W. 8. (*J. S. Jackson; J. Parrish.*)
McCOLL, Alexander Lowe, Director, Vacuum Oil Co., Ltd., Caxton House East, Westminster, S.W. 1. (*S. J. M. Auld; W. G. Gullick.*)
McMILLAN, William Hutchison, Professor of Mining (*Edinburgh University*), 5, Gordon Terrace, Edinburgh, 9. (*W. H. Cadman; W. M. Cumming.*)
MOUNTFORD, Lawrence Almeric, Trainee (*Asiatic Petroleum Co., Ltd.*), 51, Lower Park, Loughton, Essex. (*W. W. Goulston; J. Kewley.*)
MURPHY, Brian Aloysius, Chemist (*Shell Oil Co. of Australia*), 13, Dawson Avenue, Elwood, S. 3. Melbourne, Australia. (*T. M. Hartigan; J. H. Goodey.*)
NAPIER, John Watson, Engineer (*Alloa Gas Corporation*), Gas Works, Alloa, Clackmannonshire. (*A. E. Dunstan; W. M. Cumming.*)
PICKARD, William Thomas, Student, 5, The Triangle, London, W. 10. (*V. C. Illing.*)
PRESTON, Richard, Chemist (*Road Research Laboratory*), "Marand," Bath Road, Slough, Bucks. (*J. S. Jackson; J. Parrish.*)
SELLERS, Richard Wilcock, Director, (*Iraq Petroleum Company*), Caxton House East, Westminster, S.W. 1. (*S. J. M. Auld; Lord Cadman.*)
SISLEY, Harold, Student, 67, Elgar Avenue, Tolworth, Surbiton, Surrey. (*V. C. Illing.*)
THORNEYCROFT, Thomas Hamo, Director of Coal Companies, 113, St. Vincent Street, Glasgow, C. 2. (*W. H. Cadman; W. M. Cumming.*)
TRUEMAN, Arthur Elijah, Professor of Geology, University of Glasgow, Glasgow. (*A. E. Dunstan; W. H. Cadman.*)
WHITE, John Michael Willson, Assistant (*Shell-Mex & B.P., Ltd.*), Lensbury Club, Teddington, Middx. (*F. M. Harrap; W. B. Rowntree.*)
WRIXON, Reginald Bryan Bentley, Driller, c/o Anglo-Egyptian Oilfields, Ltd., Hurghada, Egypt. (*H. de Wilde; J. H. Blakiston.*)

ARTHUR W. EASTLAKE,
Honorary Secretary.

BRANCH NOTES.

ANNUAL MEETING OF AMERICAN MEMBERS.

CHICAGO, 16TH NOVEMBER, 1938.

The Fourth Annual Meeting of American members of the Institute was held at the Stevens Hotel, Chicago, on Wednesday, 16th November, 1938. Dr. J. Bennett Hill, M.Inst.Pet. (Sun Oil Company), presided over an attendance of more than 150 members and guests. The meeting was held at the same time as the annual A.P.I. Convention in Chicago.

Five short talks were given by the following speakers:

Dr. E. C. Williams (Shell Development Company) discussed "Research Angles in the Oil Industry," and referred to work on the synthesis of glycerin from petroleum gases. A small commercial plant had been in operation for more than a year, and the economic production of glycerin was a possibility. This would provide an alternative source of supply of glycerin, although it was not anyone's intent to compete with existing supplies.

Dr. G. Egloff (Universal Oil Products Company) reviewed the tendency in European countries to introduce substitutes for petroleum gasoline. He estimated that during 1939 about 25 per cent. of the total European requirements for motor fuel would come from substitutes of one type or another—mainly synthetic hydrocarbons and alcohols from coal, wood, vegetables and cereals. Experimental work was also going on with such substitutes as ammonia, hydrogen and acetylene.

*

Mr. Theron Whasson (Pure Oil Company) dealt with the geology and production activities in Illinois fields.

Dr. Frederick H. Lahee (Sun Oil Company, Dallas), Past-President of the American Association of Petroleum Geologists, discussed "Geophysical Methods in Locating Wells."

Mr. W. B. Way, of the International Petroleum Exhibition, spoke about the 1940 Exhibition to be held in Tulsa from 18–25th May, 1940.

Arrangements for the Meeting and Dinner had been made by Mr. C. R. Wagner and Mr. W. B. Ross of the Pure Oil Company, Chicago.

Trinidad Branch.

The Eleventh Annual General Meeting of the Trinidad Branch was held in the Apex Club, Fyzabad, on Wednesday, 30th November, 1938. Mr. J. L. Harris (Branch Chairman) was in the Chair.

The Committee's Report on the working of the Branch for the year and the Annual Accounts were submitted and approved. (*N.B.*—The Annual Report of the Branch will be published with the Annual Report of the Council.)

The following were elected members of the committee for the ensuing Session:

J. L. Harris, B.Sc. (*Chairman*)

L. A. Bushe — F. H. L. Tindall, B.Sc.

E. C. Scott, M.C., B.Sc. — L. K. White, B.Sc.

Honorary Secretary and Treasurer: W. N. Foster, M.A., Petroleum Office, San Fernando, Trinidad, B.W.I.

Roumanian Branch.

Mr. C. Brokaw read a Paper to the members of the Roumanian Branch on 8th December, 1938, on the subject of "Directional Drilling."

The Twelfth Annual Dinner of the Branch was held in Bucharest on 14th January, 1939. A telegram of greetings to the Council was forwarded by the Chairman (Mr. J. Rutherford) on behalf of the members present.

PERSONAL NOTES.

Mr. R. Chandler is home from India.

Engr.-Lieut.-Commdr. W. W. Downs has returned to Ceylon.

Mr. J. Mahdi is in Iraq.

Mr. M. P. McCarthy has returned to India.

Mr. J. P. McCulloch has left for India.

Mr. C. S. Newey is home from Venezuela.

Mr. C. E. Wellings has left for Iran.

Mr. H. Woodfield has left Australia and is now in Japan.

Correspondence or *Journals* forwarded to the following members have been returned, and the Secretary would be pleased to receive any information regarding their present address: T. J. F. Armstrong, E. C. Brown, K. Burton, O. C. Elvins, V. C. S. Georgescu, J. J. L. Hamilton, J. R. Horth, A. D. Jones, J. Lander, H. R. Lovely, I. Lusty, A. MacLean, G. P. Melville, C. A. Moon, R. L. Murray, S. Nicol, M. I. Oreviceanu, N. D. Rothon, H. G. Spearpoint, and A. H. Williams.

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CONTENTS.

	PAGE
Iranian Petroleum in Ancient and Medieval Times. Laurence Lockhart, B.A., Ph.D.	1
Petroleum and Bitumen in Antiquity. R. J. Forbes	19
Accelerated Oxidation as a Control Test in the Acid Treatment of Cracked Gasoline. A. Newton, B.Sc.	24
The Destructive Hydrogenation and Destruction of High Molecular Mixtures of Hydrocarbons obtained by Polymerization of Olefines. H. I. Waterman, Ph.D., and J. J. Leendertse, Ph.D.	32
Twentieth Annual Dinner	41
Some Applications of Asphaltic Bitumen in Industry. J. S. Jackson, B.Sc., F.I.C.	51
One Hundred and Eighty-fourth General Meeting	62
A Visit to Russian Oil Districts. H. G. Kugler, Ph.D.	68
The Purity of some High-Molecular Hydrocarbons as described in the Literature. H. I. Waterman, Ph.D., and J. J. Leendertse, Ph.D.	89
Note on the Determination of Neutral Oil in "Sodium Sulphonates." E. J. Boorman, B.Sc., Ph.D., A.R.C.S., D.I.C.	100
Fire Precautions in a Petroleum Laboratory. J. S. Jackson, B.Sc., F.I.C.	103
Secondary Reference Fuels for use in the Determination of Octane Numbers	106
Tank Strapping. P. Kerr, M.A., B.Sc., A.I.C.	110
One Hundred and Eighty-fifth General Meeting	125
Engine Knock and its Effect on Fuel Development. Professor D. M. Newitt, M.C., D.Sc., D.I.C., A.R.C.S.	137
The Composition of Some Roumanian Straight-Run Gasoline. C. D. Nenitzescu and A. Constantinescu	149
The Rapid Determination of Soluble Bitumen in Road Carpets. L. J. Chalk, M.Sc., A.I.C.	168
Special General Meeting	178
The Development of Fuels for Automobile Engines. Institute of Petroleum Knock-Rating Committee	181
Some Factors in Oil Accumulation. Professor V. C. Illing, M.A., F.G.S.	201
One Hundred and Eighty-sixth General Meeting	228
The Analysis of the Kerogen of Oil Shales. A. L. Down, A.R.C.S., B.Sc., D.I.C.	232
Transition Effects in Paraffin Wax. C. R. Scott-Harley	238
Knock-Rating of Aviation Fuels	252
Relation between Melting Point and Molecular Weight in the N-Paraffin Series. A. H. Etessam, B.Sc., and M. F. Sawyer, B.Sc.	253
Thermometric Determination of Transition Points in Paraffin Wax. H. D. Lord, Ph.D.	263
Analysis of Oil-Wax Mixtures. H. D. Lord, Ph.D.	277
Roumanian Branch. Twelfth Annual Dinner	288
Twenty-fifth Annual Report	293
Annual General Meeting	317
Dangerous Gases in Distillation and Refining Processes. E. Le Q. Herbert, B.Sc., F.I.C.	323
Protection against Dangerous Gases in the Operation of Cracking Units. E. J. M. Tait	347
The Detection of Gas in the Field and Refinery in Iran. Chemical Department, Anglo-Iranian Oil Company	356
The Handling of Petroleum Spirit and Solvents. F. N. Harrap, B.Sc., M.Sc.	359
The Safety of Electrical Apparatus for Use in Inflammable Gases and Vapours. C. B. Platt, M.B.E., M.I.Min.E., M.I.E.I.	368
Flame Arrestors. H. H. Radier	377
The Physiological Effects of Toxic Gases and Vapours. T. McClurkin	382
The Detection of Toxic Gases in Industry. R. B. Vallender, B.Sc., Ph.D., A.I.C.	392

PAGE

Obituary. Charles Oswald Frewin Jenkin 410

On the Gas Evolution in Petrol Storage-Tanks caused by the Activity of Micro-Organisms. A. C. Thaysen, M.Sc., Ph.D. 411

Protection from Dangerous Gases in Oil Tanks. A. W. Cox 416

Flue-Gas Protection for Ships' Tanks. O. W. Johnson, Ph.D. 426

An Automatic Recorder for Inflammable Gases. H. Lloyd, M.Eng., Ph.D., A.M.I.E.E. 435

Portable Combustible Gas Indicators in the Oil Industry. O. W. Johnson, Ph.D. 440

Vapour Detectors in the Petroleum Industry. P. Docksey, B.A. 449

The "Riken" Explosive Gas Indicator. J. S. Jackson, B.Sc., F.I.C. . . . 456

The Inflammation of Hydrocarbon–Air Mixtures. D. T. A. Townend, D.Sc., Ph.D., D.I.C., and M. Maccormac, Ph.D., D.I.C. 459

Symposium on Dangerous Gases in the Petroleum and Allied Industries . . 487

Augering and Core-Drilling for Geological Purposes in Trinidad. E. C. Scott . 501

The Measurement of the Flow Properties of Bitumens. D. C. Broome, F.C.S., M.Am.Chem.Soc. 509

Bitumen Emulsions—Their Development and Present Sphere of Utility. L. G. Gabriel, B.Sc., A.I.C. 531

The Relative Volatility of Petroleum Fractions. R. Edgeworth-Johnstone, M.Sc., M.I.Chem.E., F.I.C. 558

An Accelerated Oxidation Test for Oils. W. Francis, M.Sc., Ph.D., F.I.C., and K. R. Garrett, B.Sc. 561

A New Laboratory Method for Rating Aviation Fuels of High Octane Number. R. Stansfield, A.M.Inst.C.E., and H. B. Taylor, A.F.R.Ae.S. 568

Comparative Operating Costs of Petrol and Compression Ignition Engined Buses for Passenger Transport. W. C. Whalley, A.M.Inst.T. 573

Service Tests with Lubricants for High-Speed Oil Engines. A. T. Wilford, B.Sc., A.R.C.S., A.I.C. 607

The Lubrication of the Modern Commercial Vehicle Chassis. F. C. Whitehouse 623

The Automobile Manufacturer's Selection of Lubricants. K. Brozyna . . 629

The Efficient Burning of Fuel in High-Speed Oil Engines, with Particular Reference to a Clean Exhaust. A. T. Wilford, B.Sc., A.R.C.S., A.I.C. . . . 649

Experiments with Doped Fuels for High-Speed Diesel Engines. J. J. Broeze and J. O. Hinze 657

The Application of Graphical and Statistical Methods of Hydrocarbon Analysis to Diesel Fuels. J. C. Vlugter, H. I. Waterman, and H. A. van Westen . 678

Diesel Fuel Characteristics Influencing Engine Output. A. J. Blackwood and G. H. Cloud 684

Evaluation of Certain Normal Alkylated Benzenes as Diesel Fuels. Gann Shen, B.Sc., C. E. Wood, M.Sc., and F. H. Garner, Ph.D. 695

The Behaviour of Various Engine and Gear Lubricants in Seizure Tests. D. Clayton, B.Sc. 709

Practical Methods of Testing Lubricants. J. H. Evans 729

A Tentative Laboratory Test for the Ring-Sticking Properties of Lubricants. J. C. McNicol, C. G. Williams, M.Sc., and P. V. Lamarque, B.Sc. . . . 751

Obituary. Richard Vernon Wheeler 760

Extreme Pressure Lubricant Tests with Pretreated Test-Pieces. J. P. Baxter, Ph.D., C. I. Snow, B.A., B.Sc., and I. T. Pierce, M.Sc. 761

Some Remarks Regarding the Testing of Engine Lubricants. C. A. Bouman . 771

Piston and Piston-Ring Temperatures. P. V. Keyser and E. F. Miller . . 779

Preparation of Some Pure Hydrocarbons for the Purpose of Testing the Physical Methods in Use for the Examination of Hydrocarbon Mixtures :—

Part I. H. I. Waterman, J. J. Leendertse and D. W. van Krevelen . 801

Part II. H. I. Waterman, J. J. Leendertse and J. F. Sirks . . . 809

Correspondence 813

Author Index 821

Subject Index 824

LT.-COL. S. J. M. AULD, O.B.E., M.C., D.Sc.
PRESIDENT, 1937–1939.

[*To face p.* 1.

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IRANIAN PETROLEUM IN ANCIENT AND MEDIEVAL TIMES.*

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SYNOPSIS.

Bitumen used for various purposes in Southern Iran as far back as 5000–6000 years ago. Lack of archæological evidence in the case of liquid petroleum. Controversy over origin of the word "naphtha." Petroleum gas the fuel, in many cases, of the "eternal" fire of the ancient Iranians. The fire-temples at Shiz and Masjid-i-Sulaiman. Herodotus's account of the oil-well near Ardericca. Legendary use of naphtha by Alexander the Great. Pliny's description of occurrences of petroleum and bitumen in Iran. Petroleum used for incendiary arrows and later employed as one of the ingredients in Greek fire. The oil springs at Baku described by various Arab and European travellers. Iranian use of white naphtha for fireworks. The Hindu fire-temple at Surakhani. Peter the Great orders petroleum to be sent from Baku to Russia. Nadir Shah uses burning naphtha to scare the elephants of the Mughal army at the battle of Karnal in 1739. Origin of the word "mummy" and nature of the substance known as "mumiya" (pissasphaltos). Supposed curative properties of "mumiya" cause it to be much sought after and very highly prized in Iran in medieval times. European travellers' accounts. Ownership of petroleum rights in Iran. Revenues vested first in the Caliphate and later in the crown.

THE history of Iranian petroleum dates back to very remote times, but it is not by any means a continuous story. Every now and again there are breaks in it, some covering periods of several centuries, and we have at times only a very slender basis of fact on which to build up the narrative; sometimes, indeed, when facts are lacking, we have to fall back on conjecture.

I. BITUMEN, LIQUID PETROLEUM AND PETROLEUM GAS.

Archæological researches at Susa (Shush) have revealed that bitumen was used there in Sumerian times—that is, some five or six thousand years ago, when it was employed not only as a bonding material (as in Mesopotamia, in particular at Ur),† but also for the purpose of fixing the blades of tools into their handles and as a setting for jewels.‡ Subsequently, bitumen

* This paper is based largely upon "Persian Petroleum in Ancient and Medieval Times," an article which I contributed to the *Proceedings* of the IIe Congrès Mondial du Pétrole in Paris, in 1937. As I have in the meanwhile obtained some further information on the subject, I have taken the opportunity to modify in certain respects some of the views expressed in that article.—L. L.

† See Plate 12 on p. 54 of R. J. Forbes's *Bitumen and Petroleum in Antiquity* (Leiden, 1936). As Professor Herzfeld has stated in his article on Masjid-i-Sulaiman (see *The Naft Magazine*, Vol. V, November 1929), bitumen was not so used during either the Achæmenian or Sasanian periods. In the former epoch the masonry consisted of dressed stone held together by iron cramps; the Sasanians, on the other hand, used mortar of extremely good quality in the construction of their buildings.

‡ R. de Mecquenem's "Contribution à l'Étude des Outils en Pierre trouvés dans les Ruines de Suse," in *L'Anthropologie* (Paris, 1923), Vol. XXXIII.

was used for water-proofing pottery, as a cheaper alternative to glazing, and for caulking sea-going vessels and river craft.

Whilst archæologists have been able to establish these facts regarding bitumen, which is a solid substance, they have necessarily failed to prove whether liquid petroleum was exploited and made use of in those distant times. In the absence of archæological evidence, we have to turn to linguistics and philology, and even then to make a leap of many hundreds of years. In so doing, however, we are confronted with a serious difficulty—namely, the true origin of the word *naphtha*. Is it Iranian or Semitic?

Professors Herzfeld and Bailey state that *nafta*, from the verbal root *nab*, meaning "to be moist," came to be used in the Old Persian language to denote "petroleum," and that, in the Avestan language (which has been identified with that of the Medes),* *nafta* was changed into *napta*.† From the tongues of the Medes and Persians, *nafta* was, according to these authorities, borrowed by the Chaldeans, Hebrews and Arabs.

On the other hand, Monsieur Dhorme, the Director of the École des Hautes Études at Paris, has expressed the view that the Akkadians formed the word *nafta* from the verb *napatu*, meaning "to blaze," and that it passed from the Akkadian into the Assyrian and Babylonian languages, and thence into Hebrew, Arabic, Greek, Latin and, ultimately, into the modern European languages.‡ It is beyond the scope of this paper to take an active part in this controversy, and all that can be said here is that, whatever the origin of *nafta* may have been, the word was certainly used in Old Persian in the sense of "petroleum." It therefore follows that liquid petroleum was known in Iran in Achæmenian times, and it was doubtless utilized then for lighting, and also perhaps for medicinal purposes.

We are on more certain ground when we come to consider petroleum gas, as we know that it played, in certain cases, an important part in the religion of the ancient Iranians as the fuel of the "eternal" fire. Although these people were not, in reality, fire-worshippers, light and fire were among the dominating ideas of their religion,§ and it was therefore natural that they should build many of their temples over places where petroleum gas escaped from the ground, thus providing them with a constant and inexhaustible supply of "miraculous" fuel. The Iranians termed these fires *axvarishnik*, which means "not requiring food."‖ Such temples were constructed at Baku ¶ (as this place and its oilfields were for so many centuries within the confines of Iran they undoubtedly come within the scope of this paper),

* Darmesteter's *Études Iraniennes*, Vol. I, pp. 12 and 13 (it is to be noted, however, that German authorities like Geiger and Spiegel do not accept Darmesteter's view).

† It is curious to note that when *naphtha* was introduced into Middle English, it was given the form of *napta*.

‡ See *Le Culte du Feu dans ses Rapports avec les "Feux Eternels" et el "Naphte,"* by Messieurs Maurice Mercier and André Seguin, Paris, 1938.

§ See Professor Herzfeld's article entitled "Masjid-i-Sulaiman," in *The Naft Magazine*, November, 1929.

‖ Professor Herzfeld's *Archæological History of Iran* (London, 1936), p. 93.

¶ The late Professor Barthold, in his article on Baku in the *Encyclopædia of Islam* (Vol. I, p. 609) stated: "The assumption that the naphtha wells of Baku with their 'eternal fire' played an important part in the fire-worship of Persia . . . rests on no historical foundations; fire-worship was not brought here till the eighteenth century by Indians and Indian Parsees." Professor Herzfeld has, however, informed me that more recent researches at Baku show that the above statement by Professor Barthold is incorrect.

near Damghan * (180 miles east-north-east of Tehran) and elsewhere. The famous Arab traveller and geographer Abu'l-Hasan 'Ali, better known as al-Mas'udi (who has not inaptly been termed "the Herodotus of the Arabs"), travelled through Persia in A.D. 915. He stated that "there was in the land of Fars what was known as a source of fire and a temple was built over it"; † al-Mas'udi does not, however, give the name of the place where this temple was built.

The celebrated Græco-Arab geographer Yaqut, in his *Mu'jamu'l-Buldan*, quoting from a tenth-century writer and traveller named Mis'ar ibnu'l-Muhalhal, gives an interesting description of the great fire-temple at Shiz, the remains of which Sir Henry Rawlinson believed to be identical with the mass of ruins between Maragha and Zinjan that is now known as the Takht-i-Sulaiman ("Solomon's throne"). ‡ According to Mis'ar, § there was in Shiz

> "a magnificent fire-temple . . . from which the fires of the Magians from the east unto the west are supplied. . . . And one of the wonders of this building is that they have burnt (the fire) in it for seven hundred years, and there is no ash whatsoever found in it nor has it ever for one hour been extinguished."

This description (if we can accept it as correct) suggests the *aχvarishnik* fire.

Professor Herzfeld has expressed the opinion ‖ that, as the ancient Iranians, by reason of their religious ideas,

> "were predisposed to attach a religious significance to places like the Persian oilfields (*i.e.*, Masjid-i-Sulaiman, one of the principal fields of the Anglo-Iranian Oil Co., Ltd.) . . . we may expect that some sort of temple has existed at Masjid-i-Sulaiman at least since the Iranian occupation (about 596 B.C.)."

There thus seems some basis for Sir Henry Rawlinson's supposition ¶ that it was in a fire-temple on this spot dedicated to Anahita or Nanæa that Antiochus the Great was murdered in 187 B.C., and one might perhaps go further by surmising that it was in this temple that Neemias (as related in

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* This temple may have been situated at a spot called Shah Kuh Bala (18 miles north-north-east of the present town of Damghan), where there are petroleum seepages.

† See the *Muruju' dh-Dhahab* (edited, with French translation, by C. Barbier de Meynard and Pavet de Courteille, Paris, 1861–1877), Vol. IV, p. 79.

‡ "Memoir on the Site of the Atropatenian Ecbatana," in Vol. X, p. 70, of the *Journal of the Royal Geographical Society*. Rawlinson's opinion is supported by Professor Pope in his article "Where Rome Failed," in *The Times*, 18th February, 1938; accompanying this article is an excellent aerial view of the top of the Takht-i-Sulaiman.

§ *Mu'jamu'l-Buldan* (edited by F. Wüstenfeld, Leipzig, 1868), Vol. III, pp. 353 and 354.

‖ *The Naft Magazine*, Vol. V, November 1929.

¶ Sir H. Rawlinson's "Notes on a March from Zohab . . . along the Mountains to Khuzistan (Susiana) and from Thence through the Province of Luristan to Kirmanshah, in the year 1836," in the *Journal of the Royal Geographical Society* (London, 1839), Vol. IX, p. 85. Sir Henry only saw the ruins of the temple from afar; he was unable to visit them because of the very unsettled conditions then prevailing in that district.

Book II, ch. 1. of the Maccabees) poured water upon the stones after the sacrifice had been consumed,

> "when . . . there was kindled a flame . . . when the matter was known, it was told the King of Persia . . . then the King enclosing the place made it holy. . . . And Neemias and his party called the thing Nephtar, which is as much as to say a cleansing, but by the generality it is called Nephtai."

This passage raises two interesting questions—namely: (1) was the "water" really petroleum (*naft*), and (2) was "Nephtar" or "Nephtai" derived from the word *naft*?

The ruins of the temple now known as the Masjid-i-Sulaiman ("Solomon's Mosque"), which have given their name to the oilfield mentioned above, are, according to Professor Herzfeld,* those of a fire-temple belonging to the Arsacidan (Parthian) age, and may date from the period immediately preceding the Christian era. One is tempted to jump to the conclusion that the Mobads (priests) of this temple (and previous edifices on the same spot) may have used petroleum gas or liquid petroleum as their fuel. Geological evidence shows, however, that there could never have been an escape of natural gas from the earth just where this temple was built. Crude liquid petroleum from the adjacent seepages could not have been burnt in a fire-temple, as it would have given off quantities of smoke; since smoke was abhorrent to the Magians and Zoroastrians, who regarded it as an emanation of Ahriman, the spirit of evil, they would never have polluted their temple in this way.† As it is most unlikely that the people of those parts had, in that remote time, any knowledge of refining,‡ it seems unlikely that petroleum in any form was burnt in this temple unless the priests utilized the lighter and clearer oil resembling kerosine which, for an unknown number of years, has been collected from wells or pits dug close to the seepages at Naft-i-Safid ("White Oil"), 33½ miles south-south-east of Masjid-i-Sulaiman.

This account of fire-temples and their fuel has necessitated some departure from chronological order, and it is now necessary to revert to the fifth century B.C., when Herodotus, the first Western writer to mention Iranian petroleum, gave (in Book VI, 119, of his "History") the following description of the manner in which it was then being exploited in Iran§:—

> "Ardericca . . . is 210 furlongs (*stadia*) distant from Susa, and 40 from the well that is of three kinds whence men bring up asphalt (bitumen) and salt and oil. This is the manner of their doing it:

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* *The Naft Magazine*, Vol. V, November 1929.

† Where petroleum gas was not available, the Mobads burnt sandal-wood or tamarisk, which they laid on the fire with silver tongs; they then sprinkled incense over the burning logs. So careful were these priests to avoid defiling the sacred flame, that they wore veils over their mouths and noses (like the surgeon and the attendant nurses at a present-day operation).

‡ Mr. Forbes, in his *Bitumen and Petroleum in Antiquity* (pp. 35–39), has given an outline of the history of refining; the earliest method was that described by the elder Pliny (C. Plinius Secundus) in his *Naturalis Historia* (Books XV, 8 and XXIV, 24) who showed how "tar oil can be obtained by stretching a hide over a cauldron containing boiling pitch and then wringing out the condensed liquid."

§ This translation is by A. D. Godley (Leob Classical Library, London, 1922).

FIG. 1.

OIL SEEPAGE AT DALIKI, NEAR BUSHIRE.

N.B.—This photograph was taken some 35 years ago.

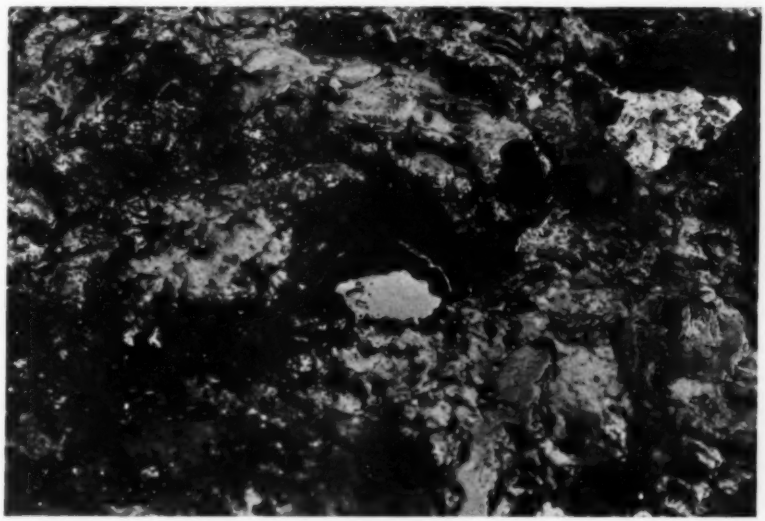

FIG. 2.

OIL SEEPAGE IN A CREEK AT MASJID-I-SULAIMAN NEAR WHERE OIL WAS STRUCK IN LARGE QUANTITIES IN 1908.

[*To face p.* 4.

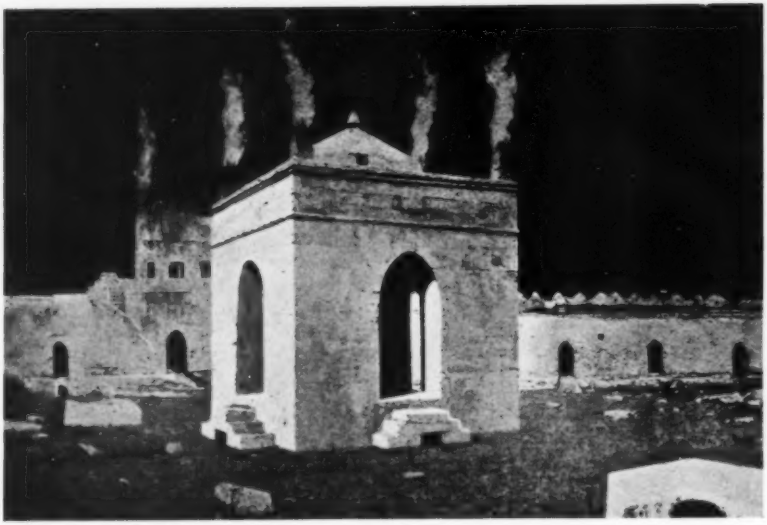

FIG. 3.

THE ANCIENT TEMPLE OF THE FIRE WORSHIPPERS AT SURAKHANI, NEAR BAKU.
(Reproduced from J. D. Henry's "Baku" by kind permission of Messrs. Constable & Co.)

FIG. 4.

THE RUINS OF THE ANCIENT FIRE-TEMPLE AT MASJID-I-SULAIMAN
("THE MOSQUE OF SOLOMON").

> a windlass is used in the drawing, with a skin made fast to it in place of a bucket; therewith he that draws dips into the well and then pours into a tank, whence what is drawn is poured into another tank, and goes three ways; the asphalt (bitumen) and the salt grow forthwith solid; the oil, which the Persians call Rhadinace,* is dark and evil-smelling."

It is unfortunate that Herodotus gave no clue to the direction of Ardericca in relation to Susa; if his distances are correct, Ardericca would have been some 25 miles from that place, whilst the oil-well would have been 5 miles from Ardericca. There are a number of ruined towns situated between 20 and 25 miles of Susa, but there are no oil indications of any importance near these. Sir Henry Rawlinson sought to identify the seepages at Qirab (literally " pitch-water "), 39 miles to the north-north-east of Susa, with the well near Ardericca, although (as he himself admits) the distance is greater than that given by Herodotus.† If, like Rawlinson, we assume that Herodotus's distances are incorrect, it seems just as, if not more, reasonable to suppose that Masjid-i-Sulaiman (62 miles east-south-east of Susa) was the site of the Ardericcan well, because the oil seepages there are more abundant and the oil itself less viscous than at Qirab.

There is a passage in Book VIII, 52, of Herodotus describing the siege of Athens by the Iranians in 480 B.C. which reads :—

> " The Persians sat down on the hill over against the acropolis . . . and besieged them (*i.e.*, the Athenians) by shooting arrows wrapped in lighted tow at the barricades."

Is it possible that these incendiary arrows were dipped in petroleum before being ignited and discharged? This conjecture is not perhaps as far-fetched as it may at first sight appear, since it is known that, in later times (see below), the Iranians adopted this method; it may well be doubted whether burning tow would keep alight when made to pass swiftly through the air, unless it were previously steeped in petroleum.

In some editions of Plutarch's *Life of Alexander* it is stated that the Macedonian conqueror, when travelling through Babylonia, was amazed at seeing flames issuing from the ground at some place " in the province of Ecbatana." He was likewise astonished when " the barbarians of this country " sprinkled liquid naphtha in the street leading to his quarters and ignited it, the flames instantly running the whole length of the street. This spectacle led to the well-known experiment that was tried on Alexander's unfortunate page, Stephen, who narrowly escaped with his life.‡

Strictly speaking, the above incidents should not be mentioned in this article, because there is reason to believe that they took place in Mesopotamia (possibly near where Kirkuk now stands). No part of Babylonia can be said, without exaggeration, to be " in the province of Ecbatana,"

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* *Rhadinace* is not a Persian word, but it was no doubt the term used at that time in Susiana (but not in Iran as a whole) to denote petroleum. It is possible that it may have been a survival from the agglutinative speech of the aboriginal inhabitants of that part.

† Rawlinson, " Notes on a March from Zohab," etc., p. 94.

‡ Plutarch's *Life of Alexander*, in his *Vitae Parallelae*, Book XXXV.

and in the more authentic texts of the *Life of Alexander* these words are omitted (it was not until later that Alexander entered the province of Ecbatana where, incidentally, there are no indications of petroleum).

Firdausi, the great epic poet of Iran, who flourished nearly 1300 years after Alexander, endeavours, in his *Shah-Nama* ("Book of Kings"), to show that the conqueror had Iranian blood in his veins and that he ruled Iran for a number of years. Firdausi gives two instances of the use of naphtha by Alexander which, though legendary, are nevertheless of sufficient interest to be mentioned here. In the first of these instances, Alexander, when ruler of Iran, is said to have built a great wall along the north-east frontier of that country in order to keep out Gog and Magog. This wall was very strongly built, the materials being fused into one homogeneous mass by means of burning naphtha and clarified butter.*

Secondly, Firdausi gives the following description of how Alexander, during his invasion of India, invented a device for scaring the elephants of Fur (Porus) †:—

> "Then the Shah
> Assembled all the master-smiths of Rum,
> Of Misr, and Pars, twelve hundred men in sum,
> Who made a horse, with saddle and with rider
> Complete, of iron, fastening the joints
> With bolts and rivets. Horse and man were furbished.
> They charged it with black naphtha, and then ran it
> On wheels before the troops. At sight thereof
> Sikander was well pleased for, being wise,
> He felt the gain thereof, and bade to make
> A thousand such and more: who'er beheld
> On chargers dappled, chestnut, black, and grey
> An iron host? The matter took the month,
> And then the workmen rested from their labours.
> Thus led they forth on wheels an iron host
> That of all things resembled horsemen most.
>
> . . . . .
>
> Now when Sikander was approaching Fur,
> And from afar one host beheld the other,
> On both sides rose the shout and dust of battle,
> And eager for the fray the warriors
> Advanced. They lit the naphtha in the steeds:
> Fur's troops were in dismay. The naphtha blazed:
> Fur's troops recoiled because those steeds were iron.
> Whereat the elephants, when their own trunks
> Were scorched, fled likewise, and their drivers marvelled.
> Thus all the Indian host and all those huge,
> High-crested elephants were put to flight.

The "robots" described in the above passage, although purely

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* *The Shahnama of Firdausi. Translated into English by A. G. Warner and E. Warner* (London, 1912), Vol. VI, p. 165.

† *Ibid.*, Vol. VI, pp. 115 and 116. A different version of this legend was current in Iran at the time when Adam Oelsläger (Olearius) was there (in 1638); according to this version, Alexander, being unable to defeat the Hebbes (? the Habashis or Ethiopians), consulted Aristotle (who, according to the legend, was with him on this campaign). Aristotle advised Alexander "to rub over with Nefte a heap of Reeds, to get them a-fire and to cast them amongst the Elephants, which were so startled at the fire, that they were put into disorder, whereupon the Hebbes were defeated, and forced to submit." (*The Voyages and Travels of the Ambassadors from The Duke of Holstein to the Great Duke of Muscovy, and the King of Persia*, London, 1662, Book VI, p. 334.)

imaginary,* are strangely suggestive of the modern tank. Curiously enough, there is, as will be seen on p. 14 below, an historical instance of the use of burning naphtha by an eighteenth-century Iranian monarch for the purpose of terrifying the elephants of his Indian adversary.

There is a further reference to petroleum in Plutarch's *Life of Alexander*,† but, as it relates to the finding of oil by the banks of the Oxus, it is doubtful whether it can properly be regarded as coming within the scope of this paper.

Strabo, in his *Geographikon*, quotes Eratosthenes (*circa* 276–194 B.C.) as having said that the liquid kind of bitumen "which is called naphtha" was found in Susis.‡ In another passage, Strabo, after describing the wall, temples and the royal palace at Susa, states that these, like the palaces and houses of the Babylonians, were built of baked brick and asphalt (*i.e.*, bitumen).§

Pliny, after describing in his *Naturalis Historia* (Book II, ch. 108) the occurrence at Samosata, in Syria, of a natural mixture of wax and pitch called *maltha* (in Greek, μάλθα or μάλθη), refers as follows to naphtha: "naphtha is a similar substance; it is so called around Babylon and in the land of the Astaceni in Parthia, flowing like liquid bitumen. It has a great affinity to fire which leaps towards it from afar, wherever it is seen." ‖

He then refers ¶ to volcanoes, such as Etna, and to what were evidently petroleum gas flares; these latter phenomena occur "in Media and Sittacene, on the borders of Persia: also in Susa at the White Tower, (the flames emerge) from fifteen openings the greatest of these (flares) being visible during the day." Pliny's meaning in regard to the "White Tower" is obscure; the words suggest a number of petroleum gas vents in a heaped-up mass of gypsum. There is a spot 20 miles to the south-west of Susa (Shush) where there are some burnt marls; no gas is escaping there at the present time, but it is possible that, at or about the time when Pliny wrote, there may have been some burning gas there; these marls and the presence of gypsum in their neighbourhood might account for the "White Tower."

Speaking of the country farther to the south, Pliny says:—

> "The river Granis which is navigable by vessels of moderate size flows through Susiana; on its right bank dwell the Deximontani, who exploit bitumen." **

As it seems clear from the record of the voyage of Nearchus that the Granis was one of the rivers of Persis or Pars and flowed into the sea a few

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* Mr. Robert Byron has suggested to me that the poet may possibly have had in mind the mechanical horsemen, clad in silk, who were grouped in phalanxes round a marvellous artificial tree at the court of the 'Abbasid Caliphs at Baghdad, in the tenth century A.D. These horsemen could be set in motion by means of their internal mechanism (see Mr. Byron's *The Byzantine Achievement*, p. 225).

† Book LVII.

‡ *Geographikon*, Book XVI, 1, 15.

§ *Ibid.*, Book XV, 3, 2.

‖ Book II, 109: "Similis est natura naphthae: ita appellatur circa Babylonem et in Astacenis Parthiae, profluens, bituminis liquido modo. Huic magna cognatio ignium, transiliuntque protinus in eam undecumque visam."

¶ Book II, 110: "Flagrat in Medis, et Sittacene, confinio Persidis: Susis quidem ad Turrim albam, e XV caminis, maximo eorum et interdiu."

** Book VI, 26: "Flumen Granis modicarum navium capax, per Susianem fluit: dextra ejus accolunt Deximontani, qui bitumen perficiunt."

miles north of where Bushire now stands,* Pliny is in error in saying that it flowed through Susiana. The Granis is apparently the Hilla Rud, some 30 miles to the north of which (and therefore on its right bank) is the Dasht-i-Qir (" Plain or Pitch " or " Bitumen "), where there are extensive seepages. It seems reasonable to suppose that the Deximontani (whoever they may have been) obtained their bitumen from these seepages.

The historian Ammianus Marcellinus, who accompanied the Roman Emperor Julian the Apostate on his campaign against the Sasanian monarch Shapur II, stated that Median oil was made in Iran. The Iranians, he said,† prepared it by soaking the leaves of a certain plant in ordinary oil. When the leaves had been steeped sufficiently, the residue was thickened by the addition of a substance " similar to common oil, a natural product of the soil . . . which is called naphtha among the Persians." An arrow dipped into this mixture, and then lighted, would set fire to anything to which it became affixed, provided that it was not discharged too forcibly from the bow, for a rapid flight through the air would extinguish the flame. If water were employed in order to put out the fire caused by this mixture, it would only become more intense, and the sole method of extinguishing it was to smother it with sand.

The above description lends some colour to the suggestion made on p. 5 above that the Iranians who besieged Athens in 480 B.C. may have utilized a similar mixture to render their incendiary arrows more effective.

Nearly two centuries after Julian's campaign against Shapur, the Iranian defenders of Petra ‡ used burning oil to destroy the battering-rams of the Roman besiegers. Procopius states, in his *History of the Wars*,§ that the Persian garrison :

> " had filled pots with sulphur and bitumen and the substance which the Medes call *naphtha* and the Greeks ' Medea's oil,' and they set fire to these and began to cast them upon the machines of the battering-rams, and they came near to burning them all."

A hundred years later, when the Byzantine Emperor Heraclius was

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* Nearchus anchored off the mouth of the Granis soon after visiting Mesembria (now the Bushire peninsula); it was not until some time later that he reached the river Arosis (now known as the Hindiyan), which formed the boundary between Susiana and Persis (see William Vincent's *The Voyage of Nearchus*, London, 1807, pp. 398–401, and Sir A. T. Wilson's *The Persian Gulf*, Oxford, 1928, p. 41).

† *Rerum Gestarum*, Book XXIII. The Latin text is as follows :—

> " In hac regione oleum conficitur Medicum, quo illitum telum, si emissum lentius laxiore arcu (nam ictu exstinguitur rapido) haeserit usquam, tenaciter cremat, et si aqua voluerit abluere quisquam, aestus excitat acriores incendiorum, nec remedio ullo, quam jactu pulveris consopitur. Paratur autem hoc modo. Oleum usus communis herba quadam infectum condiunt harum rerum periti, ad diurnitatem servantes, et coalescens durant ex materia venae naturalis, similis oleo crassiori : quae species gignitur apud Persas, quam . . . naphtham vocabulo adpellavere gentili."

In the above connection, see also B. Brissonius's *De Regio Persarum principatu* (Paris. 1599), pp. 431 and 432.

‡ The Petra mentioned here is the fortress in the Caucasus, and is not to be confused with the place of the same name in Arabia.

§ Book VIII, xi, 36. See also Gibbon's *Decline and Fall of the Roman Empire* (London, 1838), Vol. V, p. 272.

The fact that Pliny, Ammianus Marcellinus and Procopius all say that petroleum was called *naphtha* in Iran is noteworthy.

CASPIAN SEA
PERSIAN GULF
IRAN
MESOPOTAMIA
SUSIANA (KHUZISTAN)
PERSIS (FARS)
KHURASAN
TIFLIS
DARBAND
BAKU
SURAKHANI
SHIRVAN
JAWAD
ATROPATENE (AZARBAIJAN)
ARDABIL
GILAN
MAZANDARAN
ASTARABAD
SIIZ (TAKHT-I-SULAIMAN)
GAZVIN
DAMGHAN
TEHRAN
MOSUL
KIRKUK
CHIAH SURKH
EKBATANA (HAMADAN)
HIT
BAGHDAD
CTESIPHON
Tigris R.
Euphrates R.
QIRAB
ISFAHAN
SUSA (ruins)
SHUSHTAR
MELJU-I-SULAIMAN
RAFT-I-SAKIL
Karun R.
UR
Kuh-i-Bahkhaw
BEHBEHAN
ARRAJAN
SINIZ (BANDAR DILAM)
DASHT-I-GIR
ISTAKHR
DALIKI R.
SHIRAZ
Kur R.
BUSHIRE
DARABJIRD
JAHRUM
Scale of Miles
C. SEDGER

invading north-west Iran, he destroyed a number of fire-temples, in some of which petroleum gas was used as fuel.*

Contemporaneously, the Greek architect Kallinikos discovered the process for making the incendiary mixture that was generally known thereafter as "Greek fire"; it was often referred to by Byzantine historians (such as Cinnamus) as "Median fire" (*πῦρ Μηδικόν*), because the petroleum which formed one of its principal constituents was obtained for the most part from Media (*i.e.*, north-western Iran, probably the Baku district).†

The upheaval in Iran caused by the Arab invasion in the middle of the seventh century A.D. is responsible for a hiatus in the narrative of Iranian oil which lasted for over 200 years.

It is stated in the *Darband-Nama* that in the year 272 A.H. (A.D. 885/886) the Caliph of Baghdad (al-Mu'tamid) granted the revenues from the naphtha springs and salt pits at Baku to the inhabitants of Darband. Eighteen years later a man named Bi Shutur was appointed Governor of Darband; he confiscated these revenues and utilized them for his own purposes, whereupon the inhabitants of the town, "being thus deprived of all means (of subsistence), gave themselves up to trade and other employments, and there soon appeared amongst them disorder and corruption." ‡

Al-Mas'udi, as already stated, visited Iran in A.D. 915.§ Among the places which he saw was Baku, where he was much struck by the oil indications; to use his own words :—

> ". . . vessels sail to Baka (Baku) and (there is there) a spring of white naphtha and other (kinds) and there is not in the world—and Allah is the most knowing—white naphtha except in this spot, and it is (on) the shore of the kingdom of Sharwan (Shirvan), and in this naphtha-district (*nafata*) there are chimneys (*i.e.*, craters or vents) which are sources of the sources of fire which ceases not to burn." ‖

The anonymous author of the very rare tenth-century geographical work in Persian entitled the *Hudud al-'Alam* ("Regions of the World") states therein that all the petroleum used in the Dailamite country (situated to the north and north-west of Qazvin) was brought from Baku.¶

Yaqut (A.D. 1179–1229) said that Baku was :—

> "a town of the neighbourhood of Darband in the district of Shirwan in which is a large naphtha spring; it produces every day one thousand dirhams (drachms), and by its side is another spring from which flows white naphtha like oil of mercury (*dahnu'z-zibaq*) (and it) ceases not by day or night; its yield is like that of the first (well). And one of the merchants who is worthy of credence informed me that he saw there

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* Hans Höfer, *Das Erdöl (Petroleum) und seine Verwandten* (Brunswick, 1888), p. 11.

† L. Chrétien-Lalanne, *Recherches Sur le Feu Grégeois* (Paris, 1845), p. 68.

‡ See p. 136 of the *Darband-Nama or History of Darband translated from a select Turkish version by Mirza A-Kazem-Beg* (this book, which was written by Muhammad Awabi Aqtashi at the close of the sixteenth century or beginning of the seventeenth, was based on an earlier Iranian work that is no longer extant).

§ See p. 3 above for his reference to a fire-temple in Fars.

‖ *Muruju'dh-Dhahab*, Vol. II, ch. XVII, p. 25.

¶ See p. 145 of Professor Minorsky's English translation of this work.

a bit of land from which fire does not cease issuing forth day and night. I think that a fire has fallen there from some person and that it does not cease because the (combustible) mineral sustains it." *

The early thirteenth-century Iranian author who is known to us only as Ibnu'l-Balkhi (" son of the man from Balkh ") refers, in his *Fars-Nama* (" Book of Fars "), to lamp oil (*raughan-i-chiragh*) of good quality being in use at the town of Siniz (now Bandar Dilam), at the northern end of the Persian Gulf.† This oil may have come from the springs at Naft-i-Safid (it is known that, in later times, lamp oil from there was sold as far afield as Isfahan and even Tehran).‡ Ibnu'l-Balkhi omits all mention of the oil seepages at Dasht-i-Qir or Daliki.

We now come to the first medieval European to describe Iranian petroleum. Marco Polo, who travelled through the northern part of Iran in 1271–1273 gives the following description of what was evidently § the Baku field :—

" On the confines (of Armenia) towards Georgiana (Georgia) there is a fountain from which oil springs in great abundance, insomuch that a hundred shiploads might be taken from it at one time. This oil is not good to use with food, but 'tis good to burn, and is also used to anoint camels that have the mange. People come from vast distances to fetch it, for in all the countries round about they have no other oil." ‖

Hamdullah Mustaufi, the well-known fourteenth-century historian and geographer of Qazvin, makes the following statement regarding petroleum :

" *Naphtha.* There are many springs of this, but the most abundant in this kingdom of Iran is that at Baku. Here over a tract of land they have dry wells to get down to the Naphtha source, and the water which rises in these wells carries the Naphtha on its surface." ¶

A little over 200 years after Marco Polo made his journey, another Venetian, named Giosafo Barbaro, was at Baku. He described the oilfields there in these terms : —

" S'ul mare di q'sta parte è un altra città nominata Bachu, dalla-quale piglia il nome il mar di Bachu : appresso la quale è una montagna che butta olio negro, di gran puzza ; ilqual si adopra ad uso de lucerne per la notte ; ad uncione di cammelli due uolte a l'anno ; perche no gli unguendo, diuentano scabiosi " **

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* *Mu'jamu'l-Buldan*, Vol. I, p. 477.

† *Fars-Nama* (Cambridge, 1921), p. 150.

‡ Curzon's *Persia and the Persian Question*, Vol. II, p. 520.

§ In the opinion of Sir Henry Yule, the editor of the London, 1921 edition, this view appears to be correct.

‖ Vol. I, p. 46. A previous European traveller, Friar William of Rubruck, passed within a few miles of Baku in 1254, but says nothing of the oil springs in the record of his journey.

¶ *Nuzhatu'l-Qulub* (Le Strange's English translation, London, 1919, pp. 198 and 199).

** *Viaggio dello istesso Messer Iosäphat Barbaro in Persia* (Venice, 1543), pp. 55 and 56. The use of petroleum as a cure for certain human ailments and for the skin diseases of camels and other animals goes back to ancient times; see Pliny, Book XXXV, 51.

William Thomas (who was hanged at Tyburn on the 18th May, 1554, for conspiracy against Queen Mary) translated Barbaro's *Viaggio* into English; his version of the above passage is as follows :—

> "Upon this syde of the sea there is an other citie called Bachu, whereof the sea of Bachu taketh name, neere vnto which citie there is a montaigne that casteth foorthe blacke oyle, stynkeng horryblye, which they, nevertheless, vse for furnissheng of their lightes and for the anoynteng of their camells twice a yere. For if they were not anoynted they wolde become skabbie."

According to Mirza A. Kazem-Beg * a stone was discovered in the Baku oilfields early in the nineteenth-century which bore the following inscription in Arabic :

> "There is no strength and no power save in Allah the most high and the most great. Verily, Allah-Yar discovered and bequeathed this well to the Sayyids (presumably of Darband) in Rabi' II 1003." (December, 1594–January, 1595).

In 1574 Geoffrey Duckett, a factor in the Muscovy Company, visited Iran and described Baku petroleum as follows † :—

> "There is a very great riuer which runneth through the plaine of Iauat (Javad), which falleth into the Caspian sea by a towne called Backo, neere unto which towne is a strange thing to behold—for there issueth out of the ground a marueilous quantitie of Oyle, which Oyle they fetch from the vttermost bounds of all Persia; it serueth all the countrey to burne in their houses. This Oyle is blacke, and is called Nefte; they vsed to cary it throughout all the countrey vpon kine and asses, of which you shall oftentimes meete with foure or fiue hundred in a companie. There is also by the said towne of Backo an other kind of Oyle, which is white and very precious, and is supposed to be the same as that here which is called Petroleum."

Twenty-six years later, another Englishman, the preacher John Cartwright, who travelled from England to Isfahan in 1600, gave a very similar account of Baku and its oil.‡

Cartwright was followed, thirty-seven years later, by Oelschläger or Olearius, to whom reference has already been made. When the Duke of Holstein's mission was at Ardabil in 1637, on its way to Isfahan, the Governor gave in its honour an elaborate display of fireworks in which there were :—

> "several very excellent and ingenious inventions, as of little Castles, Towrs (*sic*), Squibs, Crackers, etc. In these Fire-works the Persians make use of white Naphtha, which is a kind of Petroleum; but in

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* A Kazem-Beg, *op. cit.*, p. 143.

† "Fift Voiage into Persia," pp. 439 and 440, in *Early Voyages and Travels in Russia and Persia*, Hakluyt Society, London, 1886.

‡ "Observations of Master John Cartwright in his Voyage from Aleppo to Hispaan and back againe," (in *Purchas his Pilgrimes*), London, 1625, Part II, Book IX, p. 1431.

regard this Drugg is seldome found in Europe, there may be used to the same effect, the spirit of Turpentine rectified." *

Elsewhere in his account Olearius describes the lamps used by the Iranians as being "fill'd with Rags dipp'd in Suet and Naphta." †

Strictly speaking, one ought to end off the paper at this point, because one cannot, in the ordinary way, regard the Middle Ages as extending further into the seventeenth century. However, as the methods of petroleum exploitation in Iran—and, indeed, in many other parts of the world—underwent no radical change until another two centuries had elapsed, it may not perhaps be out of place to continue this record a little further.

Sir John Chardin, who spent a number of years in Iran in the latter part of the seventeenth century, stated that both the black and the white varieties of naphtha were found in the northern province of Mazandaran. The mineral, besides being used as varnish and as an ingredient in the manufacture of paint, was also used medicinally "for curing the cold humours." ‡ Chardin stated, in addition, that petroleum was used as fuel in Iran, but he regarded "as a good joke" ("une bonne plaisanterie") the stories that had reached him of the manner in which the people in the neighbourhood of Baku used the petroleum gas there as fuel for cooking purposes; § they used to insert a tube or reed a few inches into the ground, set fire to the gas which immediately issued forth, and then placed a pot over the flame. These stories were nevertheless true, as we learn from other travellers' accounts.‖

By Chardin's time Hindus from the Panjab had evidently revived the ancient fire-worship at Surakhani (10 miles to the north-north-east of Baku), because he said that the Guebres (Zoroastrians) "who are the survivors of the fire-worshippers," showed, at a place two days' journey from Shamakhi, the spot where the "eternal fire" was burning. "They assure us," he said, "as a constant truth, that the sacred fire is still there and that those who go there for devotional purposes see it in the form of a flame." ¶ The well-known English traveller and philanthropist, Jonas Hanway, who visited Iran in 1743–1744, has given a good description of the temple at Surakhani. It is clear from what he says of the habits and peculiarities of the priests and pilgrims that they were not Zoroastrians, but Hindus.**

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* Olearius, *op. cit.*, pp. 236 and 237. The use of petroleum as an ingredient in Iranian fireworks evidently dates back a considerable time. The famous thirteenth-century poet Sa'di used the term *naft-andaz*, meaning, literally, "oil-thrower," for a kind of firework. For a comparatively recent (early nineteenth-century) description of the use of burning naphtha by a professional "fire-eater" in Iran, see Morier's *Travels* (London, 1812), Vol. I, pp. 112 and 113.

† Olearius, *op. cit.*, pp. 235 and 236. Lieut.-Colonel Chesney, speaking of petroleum and its uses in Iran a century ago, said that rags well saturated with it were burnt in an iron frame raised a few feet from the ground, and thoroughly lighted the court of a *khan* or other enclosure (see his work *The Expedition for the Survey of the Euphrates and Tigris*, London, 1850, Vol. II).

‡ *Voyages du Chevalier Chardin en Perse* (Paris, 1811), Vol. III, p. 359, and Vol. IV, p. 87.

§ *Ibid.*, Vol. II, p. 311.

‖ G. Forster's *Voyage du Bengale à Saint-Petersbourg à travers les provinces septentrionales de l'Inde*, Vol. II, pp. 346–351, and Vol. III, pp. 369–371.

¶ Chardin, *op. cit.*, Vol. II, p. 311.

** *An Historical Account of the British Trade over the Caspian Sea, with a Journal of Travels from London through Russia into Persia* (London, 1753), Vol. I, p. 381.

A further proof of this fact is that the Surakhani fire-temple bore on its walls a number of inscriptions in a Panjabi dialect and written in the Nagari script; the earliest date recorded in these inscriptions was equivalent to 1713. This fire cult continued at Surakhani until 1880.*

When Peter the Great's troops seized Baku in 1723, he sent orders to them to arrange for a quantity of petroleum to be sent from the neighbouring wells to Russia, and each one of the officers and men who formed the Russian army of occupation received a daily ration of petroleum.†

When the Iranian conqueror Nadir Shah gave battle to the forces of the Mughal Emperor Muhammad Shah at Karnal in February 1739, he used a stratagem to frighten the Indian elephants which was very similar to the one which, according to Firdausi, Alexander had employed against the Indian king Porus (see p. 6 above). It is said ‡ that Nadir :—

> " caused a number of stages to be made, and fixed across two camels. On these stages he laid naphtha and a mixture of combustibles, and ordered them to be set on fire. It is well known with what terror these huge animals (the elephants) behold this element, so instead of overturning the Persian army, at the approach of the camels the elephants turned about, and put a great part of the Indian army into confusion."

At this point we may bring the history of Iranian petroleum in the Middle Ages to a close, as there is nothing further of any interest to record until Messrs. Hotz (in 1884) and the Persian Bank Mining Rights Corporation (in 1891–1892) introduced modern drilling methods into Iran. The story of their failure and of the subsequent success of Mr. D'Arcy and the Concessions Syndicate belongs to the history of modern times.§

II. Mummy (Pissasphaltos or Mumiya).

Although the origin of the word *naphtha* is very controversial, there can be no dispute over the Iranian derivation of the term *mummy*. It has often been asserted that it is of Egyptian or Coptic origin, but that eminent Egyptologist, Sir E. A. Wallis Budge, has proved that this is not the case.‖ The substance known as mummy is a natural blend of pitch and bitumen, and the Iranians and Arabs gave it the name of *mumiya* because of its similarity to wax (*mum* in Persian). Dioscorides called it *pissasphaltos*.

By degrees the Arabs came to apply the term *mumiya* to bitumen generally. It so happened that the Egyptians used for preserving their

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* Colonel C. E. Stewart's " Account of the Hindu Fire Temple at Baku," in the *Journal of the Royal Asiatic Society*, 1897, pp. 311 and 312.

† See Soimonov's " Auszug aus dem Tage-Buche des ehmaligen Schif-Hauptmanns und jetzigen Geheimen Raths und Gouverneurs von Sibirien, Herrn Iwanowitsch Soimonow, von seiner Schiffahrt auf der Caspischen See," in G. F. Müller's *Sammlung Russischer Geschichte*, Vol. VII, pp. 332 and 333.

‡ Hanway, *op. cit.*, Vol. IV, p. 166.

§ I have given a brief account of these operations in my article entitled " Histoire du Pétrole en Perse jusqu'au Commencement du XXe Siècle," in the *Revue Pétrolifère*, Paris, 1938.

‖ *The Mummy* (Cambridge, 1925), p. 201.

dead an artificial mixture consisting of spices, resins and some bitumen. * In consequence of its bitumen content this artificial mixture also became known as *mumiya*, and a body preserved in this manner was termed *mumiyya*; *mumiya* passed into Byzantine Greek (as μουμία or μώμιον), into Latin as *mumia* (about A.D. 1000), and eventually into French and English as, respectively, *momie* and *mummy*.† Both the natural and artificial kinds of *mumiya* were reputed to have extraordinary curative properties. Sir E. A. Wallis Budge has described how the *mumiya* was scraped off the mummy wrappings and how, in time, in consequence of the high prices realized, a trade in mummies ensued. The demand grew to such an extent that corpses were bought or stolen, filled with ordinary bitumen and then treated to look like real mummies.

The first mention of natural *mumiya* in Iran that I have come across is in al-Istakhri's geographical work the *Masaliku'l-Mamalik* ("Ways of the Kingdoms"), dating from the first half of the tenth century A.D.‡ This writer states that the *mumiya* was found in a cave in the side of a mountain near Darabjird, in the province of Fars (Pars); it was so highly esteemed for its healing powers that a guard was always stationed at this cave, and, at an appointed time every year, it was collected and taken to the Sultan (*i.e.*, the Beglarbegi) or Governor of the province.§

Yaqut, on the authority of a writer named Muhammad ibn Ahmad of Isfahan, stated that the cave was in a mountain near Arrajan,‖ and that in this cave "there gushes forth a liquid like sweat from a rock and there is (obtained) from this white *mumiya* of good quality, and over this cave is a door of iron . . ." ¶ (then follow details very similar to those given by al-Istakhri as to the collection of the substance).

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* Sir E. A. Wallis Budge, *op. cit.*, p. 201; see also Forbes's *Bitumen and Petroleum in Antiquity*, p. 93. This bitumen came from the Dead Sea. Nasir-i-Khusrau, a famous Iranian traveller and Isma'ili propagandist, has described how, in his time (A.D. 1046), the substance was obtained from the Dead Sea; see his *Safar-Nama*, p. 17 of the Persian text, and pp. 57 and 58 of C. Schefer's French translation, entitled *Relation du Voyage de Nassiri Khosrau* (Paris, 1881).

† Sir E. A. Wallis Budge, *op. cit.*, p. 202; the same word was employed to denote both natural *mumiya* and preserved bodies. The following quotations from Shakespeare are of interest:—

The Merry Wives of Windsor, Act. III, Scene V.

Falstaff: "I had been drowned but that the shore was shelvy and shallow; a death that I abhor, for the water swells a man, and what a thing should I have been when I had been swelled! I should have been a mountain of mummy."

Then again, in *Macbeth*, Act IV, Scene I, we get: "Scale of Dragon, tooth of wolf, witches' mummy."

‡ His full name was Abu Ishaq al-Farisi al-Istakhri (*i.e.*, of Istakhr or Persepolis). The seventeenth-century writer Amin Ahmad-i-Razi, quoted, in his *Haft Iqlim* ("Seven Climes"), a story that had much currency in Persia in his time to the effect that one of the officers of the (legendary) king Faridun, when hunting near Darabjird, wounded a bird. He saw that this bird, after consuming some *mumiya*, was completely cured.

§ "Masaliku'l-Mamalik," in Vol. I, pp. 154 and 155 of the *Bibliotheca Geographorum Arabicorum*.

‖ M. Streck, in his article on Arrajan in the *Encyclopædia of Islam* (Vol. I, p. 460), states that *mumiya* is found in a gorge close to the Kuh-i-Behbehan, a few miles to the north-west of the ruins of Arrajan. This Kuh-i-Behbehan therefore seems to be the mountain referred to by Muhammad ibn Ahmad (Streck is in error in saying that the ruins of Arrajan are 37 miles from Shiraz; as a matter of fact, they are 140 miles west-north-west of that town. He is likewise incorrect in giving the latitude of Arrajan as 30°41′ N; it is, in reality, 30°30′ N.

¶ *Mu'jamu'l-Buldan*, Vol. I, p. 194.

Hamdullah Mustaufi, of Qazvin, after mentioning a source of *mumiya* near Arrajan, stated that it was also obtained at the village of Ayi in the district of Shabankara (Marco Polo's "Soncara") in the province of Fars.*

Sir Thomas Herbert, who was one of the suite of Sir Dodmore Cotton, the English Ambassador to Shah 'Abbas the Great, makes reference to the occurrence of *mumiya* near Jahrum, terming it :—

> "a moist redolent gum . . . sovereign against poison; and (if we may believe them) a catholicon for all sorts of wounds whatsoever, so as when other princes send Shaw-Abbas gold, pearl or like costly presents, he returns them a little of this balsam as a suitable requital." †

Engelbert Kaempfer, in his *Amoenitatum Exoticarum*, confirmed the above statement by Herbert, saying that the Iranians regarded *mumiya* more highly than pearls and precious stones, and that they gave it the honorific title of *qudrati*—that is to say, "derived from the divine power"—because it seemed to them that natural *mumiya* was a spontaneous gift of this power.‡

It is noteworthy, however, that, notwithstanding the extraordinary value which the Iranians of those times attached to *mumiya* on account of its supposedly marvellous curative properties, the foreign courts to which the Iranian monarchs were in the habit of presenting small quantities of it as a mark of their very special esteem did not always express appreciation of it. For example, when Muhammad Reza Beg, the ambassador whom Shah Sultan Husain sent to Louis XIV's court in 1715, presented the French King, as a gift from his own sovereign, with two gold boxes containing a small quantity of *mumiya*, he was the only person at Versailles to believe that his master had sent anything of particular value, and "there was indignation both at the court and amongst the public at such niggardliness which they attributed to the ambassador himself." §

Dr. John Fryer, who passed through the Shiraz district some fifty years after Herbert, says :—

> "On the right hand of the King's Highway between Siras (Shiraz) and Gerom (Jahrum) at Derab,‖ on the side of a Mountain issues the *Pissasphaltum* of Dioscorides, or Natural Mummy, into a large Stone Tank or Storehouse, sealed with the King's Seal, and that of the Calentures (*i.e.*, *Kalantars* or mayors) and all the Noblemen of that City, and kept with a constant Watch, till at a stated time of the Year they all repair thither, to open it for the King's use, to prevent its being stole; which notwithstanding, though it be Death if discovered, yet many Shepherds following their Flocks on these Mountains, by chance light on great Portions of the same Balsam, and offer it to Passengers to Sale, and sometimes play the cheat in adulterating it." ¶

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* *Nuzhatu'l-Qulub* (Leiden, 1913), p. 207.
† *Travels* (edited by Sir William Foster, London, 1928), p. 61.
‡ P. 516.
§ M. Herbette's *Une Ambassade Persane sous Louis*, Vol. XIV, p. 183.
‖ I am unable to identify Derab. It cannot be intended for Darabjird, as that place is situated 54 miles to the north-east of the nearest point on the Shiraz–Jahrum road.
¶ *Travels into Persia* (London, 1698), p. 318.

Chardin, a contemporary of Fryer, devoted a page of his *Voyages* to the subject of mummy or *mumiya*, of which, he said, there were two kinds in Iran. One of these was obtained from human bodies which had become petrified in the sands of Khurasan, and the other, which he described as "a precious gum which distils from the rock," was to be found in Kerman and Khurasan. It was, he went on to say, the Prophet Daniel who taught the Iranians how to prepare and use mummy.*

When Chardin was in Tiflis, he met Father Raphael, a Capuchin friar who was chief physician to the Prince of Georgia. This Father Raphael made Chardin "spend two Hours with an old Woman that practis'd Physick by the help of an infinite Number of Receipts, of which he caus'd me to write down some that he had heard People make the greatest Brag of, in my Table-Book." Amongst these recipes were the two following †:—

> "For Inward Pains of what sort soever, Take Potions of Mummy."
> "For all sorts of Falls, Bruises and Hurts, Take Mummy in Drink, wrap up the Patient in a Cows Hide, and let him Blood."

Although the annual ceremony of the collection of *mumiya* ceased to be held after the fall of the Safavi dynasty in 1722, the Iranians continued to hold it in high esteem. In 1784 'Ali Murad Khan, the nephew of Karim Khan Zand, sent in a gold box an ounce of the substance to the Empress Catherine II of Russia. The French traveller Comte de Ferrières-Sauvebœuf, who visited Iran during the reign of the above-mentioned 'Ali Murad Khan, stated ‡:—

> "A mountain close to Shiraz produces this precious mummy, so celebrated throughout Asia for curing in less than 24 hours all fractures, even of the most delicate bones. I have seen an experiment made on a fowl that had had its leg broken. It was made to swallow some of it mixed with butter after the fracture had been rubbed with it (*i.e.*, the mixture), and it was completely cured on the following day. Mirza Rabbi, the Prime Minister of 'Ali Murad Khan, wished thus to convince me of the effects of mummy which were so surprising that I could not have believed them before I witnessed this example."

Baron de Bode, the Russian diplomat who travelled extensively in Iran a century ago, referred to the occurrence of *mumiya* in the southern part of the country, and said:—

> "The author of these pages has himself experienced the efficacy of the Persian mumia, on applying it to a bruised side occasioned by a fall down some rocky cliffs." §

Although small quantities of *mumiya* are still collected from time to time near Behbehan, and are used to cure animals of mange, etc., it is no longer sought after as it was in the past, and it seems certain that the rapid spread

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* *Voyages*, Vol. III, pp. 311–313.

† The above quotation and the two recipes are taken from p. 234 of the English edition of Chardin's *Voyages*, which was published in London in 1691.

‡ *Mémoires Historiques, Politiques et Géographiques des Voyages faits en Turquie, en Perse et en Arabie depuis* 1782 *jusqu'en* 1789 (Paris, 1790), Vol. III, p. 33.

§ *Travels in Luristan and Arabistan* (London, 1845), Vol. I, p. 324.

of education and of modern medical methods in Iran will very soon deprive it of the small measure of importance which it retains.

III. The Ownership of Petroleum in Iran.

As it is on record that the 'Abbasid Caliph al-Mu'tamid (who reigned from A.D. 870 to 892) had the revenues of the oil springs in the Baku district in his gift (see p. 10 above), the oil rights there had evidently become vested in the caliphate at an earlier date, probably by right of conquest. *Mumiya*, as is shown by various authorities (see pp. 16, and 17 above), had been Crown property from early times. Nothing appears to be on record as to the ownership of the exploitation rights at Masjid-i-Sulaiman or Naft-i-Safid in antiquity, but there is reason to believe that they were vested in the crown until some time in the Safavi period (A.D. 1500–1722), when one of the shahs of that dynasty converted these rights into a *waqf* or pious bequest for the upkeep of the shrine at the small village of Haft Shahidan, which is situated a few miles from Masjid-i-Sulaiman. Some members of an eminent family of Sayyids (descendants of the Prophet) of the neighbouring town of Shushtar were appointed managers or rather trustees of these rights,* and they allowed the local tribes-people to exploit the oil and bitumen at Masjid-i-Sulaiman in return for the payment of certain dues. The money so accruing was used for the maintenance of the Haft Shahidan shrine. In consequence of their functions in this respect, these Shushtari Sayyids became known as the Qiri (*i.e.*, "the pitchy" or "the bituminous") Sayyids. The Qiri Sayyids subsequently undertook the exploitation of the oil and bitumen themselves, but they employed the proceeds in the same manner as before. In modern times these rights (which relate merely to the surface exudations in one particular locality, and not to the subsoil rights even there) have formed the subject of agreements between the Qiri Sayyids on the one hand and the Anglo-Iranian Oil Company, Ltd., on the other.†

Elsewhere in Iran similar rights appear always to have been Crown property.

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* Sayyid 'Abdullah ibn Nuri'd-Din, a member of this family, wrote a history of his native town entitled the *Tadhkira-yi-Shushtariya* in which he stated, *inter alia*, that bitumen from near Shushtar (doubtless from Masjid-i-Sulaiman) was used for the caulking of Iranian river-craft which took part in Nadir's Mesopotamian campaign against the Turks in 1733.

† I am indebted to my friend Dr. H. Naficy, of Tehran, for the greater part of this information regarding the Qiri Sayyids.

PETROLEUM AND BITUMEN IN ANTIQUITY.*

By R. J. FORBES, Chem.Eng. (Delft).

OF late years many petroleum technologists have shown a great interest in the early history of petroleum technology and science. Whereas formerly the only sources of information about this subject were the rather vague passages in classical literature about bitumen or petroleum, a wealth of information has now been placed at our disposal. The large number of excavations in the Near East have not only revealed a great many ancient applications of bitumen, but several inscriptions and a few texts relating to this subject have now been deciphered and published. Our knowledge of this earliest period in the history of the petroleum industry has thus been enriched to such an extent that, although not nearly all the problems have yet been solved, this phase can now be broadly outlined, and it is no longer necessary to rely on the few and often erroneous statements occurring in most petroleum handbooks.

The petroleum industry originates in the Near East. Its oldest phase is practically terminated by the fall of Babylon in 538 B.C. and the foundation of the Persian Empire. The Persians neglected the knowledge gathered by former generations; the Greeks did not take any appreciable interest in these matters, and in the Roman Empire petroleum also played only a minor part. In Greece and in the Roman Empire petroleum was found in a few places only; besides, the bituminous mortar so commonly applied in Mesopotamia was scarcely ever used in classical Antiquity, which made an ample use of the natural stone and the excellent natural mortars at its disposal. Wood-tar and pitch had come to replace bitumen.

The exploitation of bituminous products in the Near East was limited to the domains of the oldest civilizations: Egypt, Palestine, Syria and Mesopotamia. These countries form a semi-circle of fertile soil, which was aptly characterized as the " Fertile Crescent " by the American archæologist Breasted. The exploitation was restricted in these earliest times by the primitive stage of technique and science. These restrictions make it a good deal easier for us to interpret the evidence in old documents. The three principal restrictions were:

1. All bituminous products containing substantial quantities of gasoline or other volatile constituents were excluded from general application owing to their inflammability. As *distillation methods* were not discovered until the second century A.D., and not applied to petroleum before the sixth century A.D., it was impossible in Antiquity to render these inflammable petroleums suitable for use.
2. *Geological knowledge* was restricted in these days to a description of minerals from their visible characteristics. No knowledge of stratigraphy existed. It was therefore impossible to presume or detect the presence of petroleum or allied products in deeper strata.
3. Even if this geological knowledge had existed, it would have been

* Summary of lecture delivered to the Society for the Study of Alchemy and Early Chemistry on 19th October, 1938, at University College, Gower Street, W.C. 1.

impossible to produce petroleum from a great depth. Pit-mining to a depth of a few hundred metres was admittedly applied, but the *drilling technique*, so characteristic of the petroleum industry, was completely unknown in the Ancient Near East. This is all the more remarkable because the Chinese already possessed a fairly developed drilling technique a few centuries before our era.

This leads to the conclusion that the *petroleum industry in Antiquity* was of necessity confined to the *production of heavy or non-volatile petroleum products found on the surface of the earth.* The sources exploited in the first place were petroleum and bitumen seepages, deposits of natural asphalts or asphaltites and bituminous rocks rising to the surface. The exploitation therefore consisted exclusively in placer-mining and open-cut mining.

Gas wells were also known, of course; they are mentioned in the oldest literature of Mesopotamia, and burning gas wells, situated near sanctuaries, are illustrated on classical coins. In Persia the burning petroleum gases were worshipped by certain religious groups; in Mesopotamia they were only known as a natural phenomenon, though they sometimes played a part in omina and other texts making use of natural phenomena to predict the future.

Crude petroleum seems to have been scantily applied in Antiquity for illumination and heating. The thick, sulphurous crudes of the Near East seem to have given too much trouble to be generally used for such purposes. Crude petroleum was employed to a small extent in medicine and pharmacy. Yet the application of crude petroleum and allied products was practically restricted to semi-solid or solid bitumens, and it may be said that *the petroleum industry of preclassical Antiquity was essentially a bitumen industry.*

This bitumen industry had its beginning in the centuries between 3500 and 3000 B.C. From the results of modern archæological research it appears that this highly remarkable period was a turning-point in the history of civilization. Within a few centuries a neolithic, rustic population, which was scarcely differentiated, developed into the two large centres of ancient civilization: Egypt and Mesopotamia, where architecture, mining, metallurgy, etc., had reached an advanced stage of development.

Egypt plays only a minor part in the early history of the bitumen industry. Bitumen was scarce in the country itself, and according to the most reliable scientific investigations—for instance, those of Lucas—it was not applied to any marked degree until the Roman era. In this later period Dead-Sea bitumen was imported from Palestine and employed in cheap mummification processes. There are three different words in the old Egyptian papyri which have frequently been translated by "bitumen." A thorough study of the texts has shown that only one of these terms indicates a kind of glance pitch or Gilsonite from Syria, a product which, from its appearance, could be taken by the old Egyptians to be a kind of resin; as a matter of fact, it is always mentioned in conjunction with resins. In other cases the words do not denote bitumen, but animal or vegetable oil. The frequently mentioned ancient use of bitumen for mummification can therefore be ruled out as an inadmissible generalization.

Although many deposits of bitumen were known in Antiquity in *Syria and Palestine* (the Dead Sea), no data or relics are known to us showing that bitumen was also applied there.

In preclassical antiquity the bitumen industry of Mesopotamia was therefore pre-eminent. As bitumen occurred there on the surface of the earth, there were three possibilities of producing it.

The products to be considered in the first place were the *asphaltites* (glance pitch or Gilsonite). However, being hard and difficult to melt, and occurring in small quantities only, they were not of great importance.

In the second place, it was, of course, possible to exploit the rich *bituminous rocks* abundant in the mountains round Mesopotamia. Bitumen could be obtained from this source by melting down the richest parts of these rock-asphalts. For this purpose the Mesopotamians probably possessed a process: "destillatio per descens (or) ium," a jar containing the bituminous material was heated and the molten bitumen dripped through a screen into a jar underneath. This method continued in use in Europe until the nineteenth century. Agricola, for instance, gives a clear illustration of the apparatus used. There are indications that bitumen was produced in this way in Mesopotamia, but this process could never become an important one in a country devoid of wood. It is evident from old contracts that the price of this "épuré" was substantially higher than that of other types of bitumen.

The third type, *natural bitumen*, produced from pools, especially in the surroundings of the town of Hit on the Euphrates, flows up to the surface from deeper petroleum strata with gases and water. The purity of this natural bitumen equals that of the grades now obtained by distilling petroleum, and its melting point is sufficiently low for the preparation of mortars and mastics. It seems to have been sold either in its crude, natural form or freed from occluded water by pressing and heating.

Probably, a similar type of bitumen was produced by *thickening the petroleum from the seepages* by heating and evaporation, distillation being unknown. Some indication in this direction is found in the fact that Pliny mentions a process which he calls "hardening." Yet this process is not likely to have been extensively applied, because of the expensiveness of fuel already referred to.

That the bitumen from the seepages at Hit was actually the most important product of the bitumen industry in ancient Mesopotamia also follows from the fact that the name of this product forms the stem of the words for the different forms of bitumen. It is represented by a cuneiform sign connected with that for "source," so that the word for bitumen "ESIR" seems to mean "a liquid oozing up from the earth" or from the subterranean Ocean Apsû, in which the Sumerians believed. It is clear from the terminology used in Mesopotamia for bituminous products that various kinds and forms were known. The study of this terminology is facilitated by a peculiarity in Sumerian philology. The country was first inhabited by the Sumerians, who had laid the foundations of civilization and governed the country until about 2000 B.C. From 2700 B.C., and notably towards the end of this period, the country was exposed to the inroads of Semitic tribes, who, after 2000 B.C., settled there in such large numbers that they took definite possession of it. From this time onward the old

Sumerian (non-Semitic) language was gradually ousted by the Accadian (Semitic) dialects of the Babylonians and Assyrians, and relapsed to the state of a holy or temple language. The Accadians required Sumerian–Accadian dictionaries to understand this dead Sumerian language. Many of these " dictionaries " on a variety of subjects are now known to us. The Sumerian language distinguished groups of words referring to allied matters; names were formed for the various substances separately by adding " determinatives " to a radical (root or stem) common to all the members of a group. From the radical of a word it is therefore to be seen how the Sumerians classified a given substance, and from the determinative how this substance was recognized by its characteristics. A study of these lists of words shows that the Sumerians chose as the radical for bituminous products the name of the product from the pools of Hit, namely " ESIR." The various bitumens were distinguished by the determinatives placed after this radical. The Sumerians evidently knew many bitumens; for the determination of the grades we may also make use of the texts (which we could wish to be more numerous) giving information on price and application. Natural bitumen from Hit actually proves to be the cheapest. costing about 3·4 shekels per ton. This " ESIR-LAḪ " is sold in quantities averaging 2900 kg., which shows that we may actually speak of a bitumen *industry*. In addition to this, the texts mention small quantities of rock-asphalt from the mountains or of the " épuré " prepared from this, at twice this price or higher.

The bitumen was used for the preparation of bituminous mastics or mortar, for which purpose it was melted and mixed with sand and loam. It has become evident from the examination of samples collected from excavated monuments that two kinds of mixtures were made: very rich mixtures with about 35 per cent. of bitumen for mortars and less rich ones with about 25 per cent. of bitumen for mastics or mastic asphalt compositions. Compared with the mixtures now employed, these ancient mixtures were very rich in bitumen, but they had the advantage of possessing the right painting or trowelling consistency at fairly low temperatures. They became soft, of course, in the sun's heat, but the old Sumerians knew a way out of this difficulty by adding a small percentage of chopped straw, reed or other fibrous material, thus preventing the mastic from flowing in the sun. The analysis of old mastic samples containing this fibrous material presents the advantage that we get to know something about the vegetation of Mesopotamia in those days.

The *mastics* were usually prepared on the spot; though this substance " ESIR-É-A " (literally building-bitumen) also occurs in contracts of sale, only small quantities are mentioned and (owing to the high price of fuel) it was twice as expensive as it is at present. Unlike the other bitumen grades it was sold by volume, not by weight, for, after being prepared, the hot mastics were cast to cakes in flat baskets or other moulds. This may be clearly seen from a lump of mastic found in the " Flood Layer " of Ur.

These mastics were chiefly applied in floorings or for the sealing of brick-work, mostly in those parts of important buildings where rain or river water might damage unprotected bricks, since the Mesopotamians frequently used unbaked bricks made of sun-dried clay.

The *bituminous mortar* was applied in the joints of pavements of stone

slabs, as well as in the masonry (of braked bricks) in temples and palaces. In combination with bricks which, being baked at a low temperature, were highly porous, this mortar gave a firm masonry, which has resisted the ages. This is borne out by the embankment built about 1350 B.C. at Assur which is still watertight in spite of the fact that the level of the river has risen considerably. In addition to being widely applied in architecture and civil engineering (which excited the admiration of the classical authors) bitumen was used in small quantities for sealing or repairing ships (guffahs) aqueducts, etc.

That an extensive use was made of bituminous mastics is proved by a recently found clay tablet, which mentions, in a detailed list, the quantity of bitumen required for laying a mastic asphalt floor of given thickness and area.

Special Applications.

The cores of statues were frequently made of mastics and cast in moulds; these cores were then covered with copper or gold foil so as to make the impression that highly intricate sculpture had been cast in metal.

Ornamental inlay-work or mozaic panels of mother of pearl and coloured stones in mastics are very common.

Natural asphalt itself—*i.e.*, the bituminous rocks from the mountains—was also used for sculpture. The Sumerian sculptors have shown that with this plastic material they could achieve more than might be presumed from the frequently clumsy statues in natural stone, which for them was very costly and rare.

Bitumen was extensively employed in medicine and magic art; many applications in agriculture have become known from classical authors.

These are the principal facts about the oldest phase of the petroleum industry.

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ACCELERATED OXIDATION AS A CONTROL TEST IN THE ACID TREATMENT OF CRACKED GASOLINE.*

By A. Newton, B.Sc.

Synopsis.

The working up of acid-treated cracked distillates in the laboratory has been found to give products with induction periods which cannot be related to the treatment given. This effect has been connected with the presence of "natural" oxidation inhibitors which are in general removed to different extents by laboratory and plant treatments. A method of removing such inhibitors from gasolines by treating with a solution of an aromatic diazonium chloride in alkaline solution has been developed, and has been shown to give inhibitor-free products without affecting other properties of the gasoline, thus permitting the effect of treatment and the effect of inhibitors to be determined separately. The application of this method is discussed.

The accelerated oxidation test [1, 2, 6, 8, 11, 15, 16, 18] supplies a convenient method of estimating how long cracked gasoline is likely to remain free from excessive amounts of gum when kept in storage. The test is used in two modifications, the first of which consists in determining the gum content of the sample after exposure for, say, four hours to the conditions of the test. The second modification consists in running the test until the rapid absorption of oxygen associated with the induction period commences to take place, and taking the length of the induction period as a measure of stability. The second of these modifications is, in the writer's opinion, the more convenient for use for the control of chemical treatment of pressure distillate, and has been used for several years for that purpose in the Pointe-a-Pierre laboratory. The first method merely shows whether sufficient treatment has been given, but provides little indication of over-treatment.

The method of preparing the sample for test is as follows : The sample of pressure distillate is taken at the treating plant at a point at which the distillate has received two preliminary caustic-soda washes, an acid treatment, a water wash and a final caustic-soda wash, and is ready for re-running. This sample is re-run in the laboratory with steam through a 6-in. Hempel column to take off a gasoline cut of 205° C. end-point comprising about 85 per cent. by volume of the pressure distillate. The distillate is washed once with caustic soda, sweetened with plumbite and sulphur, washed with water until neutral and finally dried by filtration. One hundred and fifty ml. of this sample are tested in a 400-ml. steel bomb with oxygen at 100 lb. per sq. in. (gauge) initial pressure and 100° C. Induction periods determined in this manner have been found to be reproducible within 30 minutes except when very high, when the variation is liable to be appreciably greater.

Recently an attempt was made to establish a correlation between the

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* Paper presented at a General Meeting of the Trinidad Branch held at the Apex Club on December 1, 1937, Mr. J. L. Harris in the Chair.

conditions of acid treatment and the oxidation stability of the product, by collecting and correlating daily induction period results with the amount of acid treatment. It was not possible to obtain any correlation and, in fact, the data showed extraordinary anomalies. As, however, two different types of pressure distillate and varying mixtures of these were being treated over the period in question, the issue was somewhat obscured, and no reason for the anomalies could be assigned.

A little further investigation showed that if any given sample of cracked distillate was divided into two portions, and these two portions were prepared separately for testing, the induction periods of the two finished gasolines were frequently different, although all reasonable precautions were taken to carry out the two treatments in an identical manner. In extreme cases differences amounting to several hours were encountered. On consideration it appeared that the failure to obtain duplicate results on samples prepared by an apparently duplicate treatment could only be associated with the presence in the gasolines of "natural" oxidation inhibitors.

It has been known for many years that cracked gasoline from Trinidad stocks contains appreciable quantities of phenols such as have been found in crude oils [7, 14] and cracked products [3, 4, 13, 17] from other sources. It has also been known, and has been demonstrated elsewhere,[12] that these phenols act as oxidation inhibitors, or, to use a more popular term, gum inhibitors, as little as one part in fifty thousand parts of gasoline being sufficient to increase the induction period by six or seven hours, or to delay the appearance of gum in appreciable quantity for four or five months under ordinary storage conditions. However, while it is known that phenols are present in many, probably in most, cracked distillates, especially those from residual charging stocks, it does not seem to be generally appreciated that their removal by any of the customary methods of chemical treatment to such an extent that the residue is insufficient to affect the induction period of the gasoline by more than, say, 15 minutes, is a matter of some difficulty.

The ease of removal of acidic substances from oil solution by caustic-soda washing is determined by two circumstances : [10]

(1) The higher the dissociation constant (or strength) of the acid the more easily is it removed;

(2) The higher the ratio of the solubility of the free acid in oil to its solubility in water, the less easily is it removed.

The common monocyclic phenols are very weakly acidic, having dissociation constants of the order of 2×10^{-8}. Moreover, with the exception of phenol itself, they are rather sparingly soluble in cold water, but are readily soluble in gasoline. Both these circumstances militate against their easy removal from oil solution by soda washing. In order to assess the difficulty of removal in terms of the laboratory operation of soda washing, a quantity of treated cracked gasoline was soda-washed a number of times with 10 per cent. by volume of 2 per cent. caustic-soda solution, removing a portion of the oil after each wash and taking the induction period of this portion as a measure of its phenol content. The same operation was also carried out by using 10 per cent. caustic soda instead of 2 per cent. The results are given in Tables I and II.

TABLE I.

Effect of Washing with 2 per cent. NaOH on the Induction Period of Cracked Gasoline.

No. of Soda Washes.	Induction Period, mins.
0	1320
1	1020
2	960
3	565
4	480
5	420
6	255

TABLE II.

Effect of Washing with 10 per cent. NaOH on the Induction Period of Cracked Gasoline.

No. of Soda Washes.	Induction Period, mins.
0	1320
2	495
4	195
6	210
8	195
10	150
12	120

As would be expected, the stronger soda effects more rapid removal, but even in this case the removal of the last traces of phenols is extremely slow.

It may be noted here that the effect of soda washing and doctor treatment in reducing the induction period of East Texas cracked gasoline was reported by McNamara,[9] but no particular significance appears to have been attached to it.

Numerous repetitions of the soda-washing experiments fully confirmed the difficulty of removing the last traces of phenols, and established beyond doubt that the lack of reproducibility in the routine testing method was connected with this stage of the working up. However carefully the operations were carried out, there was in general enough difference between the amounts of inhibitor removed in duplicate procedures to cause a considerable difference between the induction periods of the products. The difference in the amounts removed need not be very great. Some idea of the sensitiveness of the gasoline to inhibitor concentration can be gained from the figures in Table III, which were obtained by adding various amounts of a distillation fraction of pressure distillate phenols to an inhibitor-free cracked gasoline.

The effect is not quite regular, but on the whole the inhibitor shows the peculiarity that increasing amounts exert more than a proportional effect. With most inhibitors the reverse is the case. The increase in induction period with increase in phenol concentration per 100 ml. of gasoline is on the average about one hour per milligram.

TABLE III.

Effect of Concentration of Phenols on the Induction Period of Cracked Gasoline.

Grams of Inhibitor per 100 ml. of Gasoline.	Induction Period, mins.
0	120
0·005	540
0·01	765
0·02	2055*
0·03	4230*

* These tests showed no sharp break, the pressure falling slowly and continuously. The break was arbitrarily taken as the point at which the pressure had fallen 2 lb. per sq. in. below the maximum.

The significance of these results is greater than attaches to the duplication of a control test. Unless the presence of natural inhibitors is taken into account, or preferably unless they are completely removed, the results of work on the chemical treatment of cracked gasoline with the object of improving its potential gum content will not be truly indicative of the effect of the treatment used, but will be the combined result of the treatment and of the effect of inhibitors. Moreover, if the treatment used involves any step which is likely to alter the concentration of inhibitors to a variable extent, as most treatments do, the results will have no significance whatever. Similarly the testing of gum inhibitors will give erroneous results if carried out on cracked gasolines which already contain natural inhibitors.

Consideration of the reactions of phenols as a class indicated that it might be possible to find a more positive method of removing them from gasoline than exhaustive soda washing. Such a method can, in fact, be based on the diazo-reaction. If an aromatic amine such as aniline is dissolved in hydrochloric acid, and an aqueous solution of sodium nitrite is added, the diazonium chloride which is formed reacts rapidly and usually completely with phenols in alkaline solution to form azo-dyestuffs. By shaking a sample of gasoline with caustic-soda solution, the phenols originally present in the gasoline distribute themselves between the oil and aqueous layers in a definite ratio. On adding a solution of diazonium chloride to the system, reaction (usually termed " coupling ") takes places with the phenols present in the aqueous layer with formation of azo-dye, and the distribution of phenol between oil and water is disturbed. Consequently more phenol passes from the oil layer to the water layer, and reacts until the whole of the phenol has been removed from the oil and converted into azo-dye. Although the reaction must take place in the aqueous layer, the resulting dye does not necessarily remain in this layer, since the dyes from phenols and many aromatic amines are soluble in gasoline, but not in water or caustic soda. A soda-soluble, gasoline-insoluble dye may be formed by using an amine which contains an acidic group, such as the sulphonic-acid or carboxylic-acid group. With these considerations in mind, sulphanilic acid (aniline *p*-sulphonic acid) was chosen for use in the experiments now to be described.

A quantity of steam distillate was prepared from a sample of acid-

treated pressure distillate and a portion set aside for induction-period determination. The remainder without previous treatment was washed with an alkaline solution of the diazo-compound from sulphanilic acid and a portion of the product reserved, the remainder being given a second diazo-treatment and so on. The results are given in Table IV.

TABLE IV.

Effect of Diazo-treatment on the Induction Period of Cracked Gasoline.

No. of Diazo-treatments.	Induction Period, mins.	Deviation from Mean, mins.
0	810	—
1	435	—
2	285	+33
3	255	+ 3
4	195	−57
5	255	+ 3
6	270	+18
Mean of last five	252	

With the exception of the fifth result, these are very satisfactory, and indicate that constancy of induction period (complete removal of inhibitors) is attained after two diazo-treatments. On repetition it was found that the number varied between two and three, but that if the diazo-treatment was applied to the distillate after soda washing and sweetening with plumbite in the usual manner, a single wash sufficed to prepare an inhibitor-free product. This is shown by the two samples in Table V.

TABLE V.

Effect of Plumbite Sweetening followed by Diazo-treatment on the Induction Period of Cracked Gasoline.

No. of Diazo-treats.	Sample No. 1.		Sample No. 2.	
	Induction Period, mins.	Deviation from Mean, mins.	Induction Period, mins.	Deviation from Mean, mins.
0	495	—	285	—
1	240	−25	165	+27
2	270	+ 5	150	+12
3	285	+20	120	−18
4	330	+65	135	− 3
5	225	−40	135	− 3
6	240	−25	120	−18
Mean of last six	265	—	138	—

Note.—Sample 1 of Table V is the same product as the sample of Table IV.

The method finally adopted for working up samples to obtain inhibitor-free induction periods is as follows :

The pressure distillate is steam distilled through a 6-in. Hempel column packed with 5-mm. glass beads until a 205° C. end-point distillate has been

removed. The steam distillate is washed very thoroughly with 10 per cent. by volume of 10 per cent. caustic-soda solution and sweetened with plumbite and sulphur. For the next operation two solutions are required.

(1) Ten grams of sulphanilic acid are dissolved in 100 ml. of 12*N*-hydrochloric acid and 200 ml. of water by boiling and, after cooling, the solution is made up to 1000 ml.

(2) A solution of sodium nitrite is prepared by dissolving 18·1 g. of the salt in water and making up to 1000 ml.

To the sweetened distillate 40 ml. of 10 per cent. caustic soda and 160 ml. of water are added and the mixture is shaken vigorously. The soda is left in contact with the oil. Fifty ml. of solution (1) are placed in a 200-ml. flask, cooled in ice and 10 ml. of solution (2) added. The resulting solution of diazotized sulphanilic acid is shaken for a few seconds in the ice-bath, then added to the oil-soda mixture and shaken very vigorously for two or three minutes. The removal of phenols is indicated by the development of a yellow to deep reddish-orange colour in the aqueous layer. After settling for five minutes, the aqueous layer is run off and the oil washed with water until free from alkalinity.

The routine use of this method of preparing samples has shown that induction periods can consistently be duplicated within the limits of experimental error. It has also shown that the true induction period (inhibitor-free) of cracked gasoline rarely exceeds 250 minutes, and is usually somewhat lower, and that the course of induction period improvement by acid treating is rather different from that previously found. An initial, relatively small treat appears to remove the whole of the highly unstable di-olefines which are present to the extent of about 1 per cent. in liquid-vapour phase-cracked distillate. Increase in the amount of the treatment thereafter produces a comparatively small improvement in induction period corresponding to a slight decrease in the ratio of mono-olefines to saturated hydrocarbons in the residual spirit.

Apart from its routine use, the diazo-treatment has been of value in obtaining inhibitor-free materials for investigational purposes. The treatment has the advantage of not affecting other important properties of the cracked gasoline. In particular colour stability, which is usually rather susceptible to the action of reagents, is not changed by this treatment. This is illustrated by the results in Table VI.

TABLE VI.

Effect of Diazo-treatment and Inhibitor on Dark Colour Reversion.

	A.	B.	C.	D.
Amount of inhibitor, g./100 ml. .	a	0	0·005	0·02
Colour after 0 days . . .	28	28	27	26
" " 14 " . . .	27	26	26	26
" " 28 " . . .	27	27	26	27
" " 56 " . . .	26	26	26	25
" " 84 " . . .	27	26	26	27

Note.—A, gasoline sample with unknown amount of inhibitor. B was prepared from A by exhaustive diazo-treatment, and was used as the base for preparing C and D by addition of the specified amount of natural inhibitor.

There is a possible limitation to the use of the diazo-treatment. Diazo-compounds couple with phenols in the position *para*- to the hydroxy-group, or if this position is already occupied in one of the two *ortho*-positions. If both *ortho*-positions and the *para*-position are already occupied by alkyl or other groups, coupling does not take place (although in certain cases groups other than alkyl already present in the *para*-position may be displaced by the diazo-group). So far as is known, the phenols of cracked gasoline are largely mono- or poly-methyl derivatives of phenol, and of these the highest members to be expected in gasoline of 205° C. end-point are the trimethyl-phenols, which boil in the neighbourhood of 230° C. at atmospheric pressure. Of all the possible trimethylphenols, the only one which has neither *para*- nor *ortho*-positions unoccupied is mesitol (2 : 4 : 6-trimethylphenol). If this were present it, at least, would certainly not be removed by the diazo-reagent. However, it is known [5] that the inhibiting efficiency of different alkyl phenols varies very considerably, and it appeared possible that failure to remove certain individual phenols, if present, might not affect the oxidation stability of the otherwise inhibitor-free product. To test this point a quantity of phenols was separated from spent caustic soda which had been used in the preliminary soda-wash of raw pressure distillate. After purification, the phenols were fractionally distilled *in vacuo*, and the effectiveness of each fraction was tested on a sample of cracked gasoline which had been previously exhaustively diazo-treated. Fifty milligrams of each fraction per 100 ml. of sample were used in each case. The results are set out in Table VII.

TABLE VII.

Oxidation-inhibiting Efficiency of Fractions of Pressure Distillate Phenols.

Boiling Range of Fraction at 10 mm., ° C.	Yield of Fraction, per cent. of Total Phenols.	Induction Period, mins.
Uninhibited gasoline	—	90
76– 86	15·9	705
86– 96	20·6	945
96–106	14·3	675
106–116	7·1	300
116–126	15·0	115
126–127	4·0	75

These results show an initial increase in effectiveness followed by a decrease, until in the fraction, b_{10} 116–126° C., corresponding approximately to the trimethylphenols the effect is practically nil. It is thus immaterial whether or not these higher-boiling constituents are removed. The cresols and xylenols are evidently the most active constituents of natural phenolic inhibitors.

I have to acknowledge my indebtedness to Mr. P. H. B. Trasler for carrying out the large number of induction-period determinations required during the course of this work, to Mr. E. A. Richardson for much of the treating work and to Messrs. Trinidad Leaseholds, Ltd., for permission to read this paper.

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THE DESTRUCTIVE HYDROGENATION AND DESTRUCTION OF HIGH MOLECULAR MIXTURES OF HYDROCARBONS OBTAINED BY POLYMERIZATION OF OLEFINES.*

By H. I. Waterman (Hon. Member) and J. J. Leendertse (Associate Member).[1]

Introduction.

Some years ago Perquin and others undertook the study of the changes which occur in hydrocarbon mixtures when they are heated to 400–600° C. under high pressure. In particular, hydrocarbon mixtures of paraffinic nature (*e.g.*, Rangoon paraffin wax) were chosen, these materials being very suitable for proving an eventual formation of cyclic compounds under these conditions. The nature of the reaction products was always difficult to determine, since, even very soon after the commencement of the experiment, the number of compounds present was very large. At that time the investigation had usually to be carried out by separating the components and identifying the compounds so obtained. Later, however, a method was devised for determining the nature of hydrocarbon oils by analysing the mixtures as such,[2] instead of separating out the individual compounds. As a result the reaction products from the destructive hydrogenation and destruction experiments could be analysed more simply. In this way it was proved that the hydrocarbon molecules of the Rangoon paraffin wax could be cracked without any ring formation. This occurred when the material was heated in an atmosphere of hydrogen under high pressure in the presence of a hydrogenation catalyst. However, when this was repeated in the absence of a hydrogenation catalyst or without hydrogen at high pressure, the reaction products contained cyclic compounds.[3] The formation of ring structures under these conditions could be explained by side reactions of the (partly) unsaturated aliphatic products formed during the primary cracking of the paraffin molecules of the raw material. When reaction conditions are favourable for the unsaturated products to become hydrogenated (*e.g.*, experiments in the presence of high-pressure hydrogen and a hydrogenation catalyst), side reactions involving ring closure will scarcely be possible, since the unsaturated linkages are rapidly hydrogenated.

Similar experiments were carried out on some cyclic raw materials of natural origin—namely, an extract and a raffinate from a Borneo lubricating-oil fraction.[4] Here again a breaking-down was observed. The total number of rings in the reaction products, however, was practically equal to that in the raw materials used. So, contrary to the results with Rangoon paraffin wax, no formation of extra rings was found here.

Since up to now only products of natural origin had been investigated, a study of the behaviour of some synthetic hydrocarbon mixtures under comparable conditions should prove interesting.

* Paper received October 30th, 1938.

Some preliminary experiments with fractions obtained from the polymerization products of *n*-pentene-2 with aluminium chloride at about 0° C. have already been described.[5] These hydrocarbons were mainly paraffinic. With this material the results obtained in some of the experiments indicated that "depolymerization" had occurred,—*i.e.*, a regular breaking-down, in which the cyclic character (and other properties) of the reaction products change with the molecular weight in the same way as they do when polymerization occurs, but in the opposite direction. Under certain conditions—for example, at high temperature—ring formation was definitely proved. Furthermore, the results indicated that the breaking-down of these polymers was much more rapid than that of the natural products mentioned above.

In this connection attention may be directed to the work of Ipatiev [6] and others, from which it may be seen that the reactivity of a paraffin increases with increasing molecular weight and degree of branching. *Iso*-octane, 2 : 2 : 4-trimethylpentane, for example, undergoes deep-seated changes in the presence of aluminium chloride activated with hydrochloric acid at 20–50 °C., when a part of the reaction products consists of *iso*butane. The rapid depolymerization of branched hydrocarbons such as 2 : 2 : 4- and 2 : 2 : 3-trimethylpentane is shown also by the behaviour of these hydrocarbons with 97 per cent. sulphuric acid. In this case C_4-hydrocarbons are formed even at room temperatures.[7]

In view of the results mentioned above, experiments with synthetic hydrocarbon mixtures were continued and improved. A summary of the results obtained will be given below.[1]

Raw Materials.

Some of the experiments were carried out with a mixture of hydrocarbons obtained by the polymerization of *iso*butene with aluminium chloride at room temperature. The fractions used were derived from the polymers by a cathodic light vacuum distillation with internal condensation followed by careful hydrogenation. The mixtures obtained in this way were *completely saturated, highly branched and mainly paraffinic* in nature, though ring compounds were not completely absent. (The products are indicated as B_2, B_3, and B_4 in Table I and contain 0·8–1·05 rings per molecule at molecular weights of about 450–480.)

Other experiments were carried out with synthetic highly *cyclic* hydrocarbons. The latter were obtained from the polymerization products of *cyclo*hexene and aluminium chloride at about 70° C. A product derived from the "A. oil" of the polymerization as well as a mixture from the "B. oil" were used.[8] In most cases these fractions were used as such without any previous hydrogenation (C_1 and D_1 in Table I). Only in the experiments with high-pressure hydrogen and a nickel hydrogenation catalyst were the raw materials first carefully and completely hydrogenated (C_2 and D_2). The number of rings per molecule were respectively in the "A. oil" (mol. wt. about 350) and the "B. oil" (mol. wt. 370) 4 and 5–6.

Also, for comparative purposes, experiments were carried out with a distillate fraction from a Pennsylvanian mineral oil.

The physical constants of the hydrocarbon mixtures are indicated in Table I. The complete analysis of the mixtures is given, as are the

TABLE I.

Physical Constants.	Mixture of *iso*butene polymers.			Mixture of *cyclo*hexene polymers "A. oil."		Mixture of *cyclo*hexene polymers "B. oil."		Distillate fraction of Pennsylvania oil.		
	After hydrogenation.	After hydrogenation.	After hydrogenation.	Before hydrogenation.	After hydrogenation.	Before hydrogenation.	After hydrogenation.	Before hydrogenation.	After hydrogenation.	Predicted after complete hydrogenation.
Raw material indicated as	B_2	B_3	B_4	C_1	C_2	D_1	D_2	G_1	G_2	—
n_D^{20}	1·4702	1·4695	1·4680	1·5229	1·5131	1·5370	1·5175	1·4870	1·4818	—
d_4^{20}	0·8478	0·8453	0·8418	0·9740	0·9528	0·9978	0·9767	0·8754	0·8708	—
$\frac{n^2-1}{n^2+2}\cdot\frac{1}{d}$ (D)	0·3292	0·3298	0·3302	0·3136	0·3155	0·3130	0·3100	0·3285	0·3273	0·3268
Mean molecular weight	446	481	480	345	348	369	370	517	—	—
Aniline point observed, ° C.	129·1	126·0	123·7	74·4	78·5	57·8	87·0	111·8	115·1	—
Ditto from graph, ° C.	118	121·5	122	—	86	—	82	122·5	121	120
Mean number of rings per molecule	1·05	0·85	0·8 (0·77)	4·1	4·1	5·7	5·7	1·85	1·85	
Chlorine, %	—	—	0·1	—	—	—	—	—	—	—

properties of the completely hydrogenated Penna oil, although in the experiments the non-hydrogenated material was used.

Description of the Experiments and Results.

All the experiments were carried out in rotating autoclaves at 435° C. under standard conditions. The oils were always heated in the presence of hydrogen or nitrogen under high pressure (initial pressure 80 kg./cm.^{2} at room temperature). When hydrogen was used, either no catalyst was present or 10 per cent. nickel-on-kieselguhr. With nitrogen 10 per cent. nickel was always present.

The experiments were quantitative, the quantities of gaseous and liquid products being determined as accurately as possible and always in the same way. The gases were analysed and the average number of C atoms per molecule in the gaseous paraffins determined. The liquid product was fractionated quantitatively under standard conditions and the fractions were analysed by the specific refraction molecular weight method.[2] Sometimes a careful non-destructive hydrogenation of the fractions was necessary for the analysis. Thus the number of rings per molecule in each fraction could be deduced. As the molecular weight and quantity of each fraction were also determined, the total *number of rings* in each fraction, and hence in the whole product, could be calculated and compared with the total number of rings in the corresponding quantity of the starting material.

The following conclusions may be reached from the results of the experiments with the *iso*butene polymers.

1. *The isobutene polymer mixtures in question are relatively very unstable under the conditions of the experiments.* Even after a time of reaction of 1 minute (*i.e.*, a rapid heating to 435° C. immediately followed by a rapid cooling of the autoclave), an unexpected and very marked destruction was observed. This breaking-down was much more marked than that of the Penna-oil fraction under the same conditions. (Rangoon paraffin wax, held at 435° C. for 1 minute, also only breaks down to a very small extent).[9] A comparison of the rates of cracking of the polymers and the Penna-oil fraction is given in Table II,* which clearly indicates the relative instability of the polymer mixtures.

2. *The rings in the polymer mixtures are also relatively unstable.* Table II illustrates this for two experiments with *iso*butene polymers. It may be seen that the total number of rings in the reaction products is much lower than in the corresponding quantity of the raw material. The total number of rings in a Penna-oil fraction, however, did not change under the same conditions (Experiment 9). The experiments described in Table II are given only as examples, the results of several other experiments, where the

* In all the tables the raw material is designated in the same way as in Table I—*e.g.*, B_3 is the *iso*butene polymer mixture B_3 mentioned in Table I. When the experiment is one in which hydrogen or nitrogen at high pressure is used, this is indicated by H_2 or N_2, respectively. The reaction time given is the time of heating at 435° C. Thus, for example, B_3, H_2, 1 minute means an experiment with raw material B_3 with high-pressure hydrogen heated for 1 minute at 435° C.

TABLE II.

Number of the experiment.	7.	8.	9.
Raw material and conditions of reaction.	B_2, H_2, 1 min.	B_4, Ni + H_2, 1 min.	G_1, Ni + H_2, 1 min.
First gas fraction, % [1]	3	5	3
Hydrogen in the gas, %	100	93	100
Unsaturated hydrocarbons, %	0	6	—
Mean number of C atoms per mol. in the paraffinic part	—	1	—
Second gas fraction, % [1]	5	15	(0·1)
Hydrogen in the gas, %	38	3	89
Unsaturated hydrocarbons, %	13	1	0
Mean number of C atoms per mol. in the paraffinic part	4	2·3	2·6
Third gas fraction, % [1]	4	8	(0·07)
Hydrogen in the gas, %	0	0	0
Unsaturated hydrocarbons, %	17	0	0
Mean number of C atoms per mol. in the paraffinic part	4	3·9	2·6
First liquid fraction, % [1]	13	10	2
Boiling point, ° C.	<50	20–60	<40 (3 mm.)
Molecular weight	70	78	104
Number of rings per mol.	0	0	0·9
Second liquid fraction, % [1]	15	16	—
Boiling point, ° C.	from 50 (750 mm.) to 80 (80 mm.)	60–140	—
Molecular weight	113	108	—
Number of rings per mol.	0·1	0	—
Third liquid fraction, % [1]	16	14	—
Boiling point, ° C.	C.V.D.I.C.[2]	from 140 (760 mm.) to 105 (30 mm.)	—
Molecular weight	224	152	—
Number of rings per mol.	0·4	0·2	—
Fourth liquid fraction, % [1]	20	—	—
Boiling point, ° C.	C.V.D.I.C.[2]	—	—
Molecular weight	390	—	—
Number of rings per mol.	0·6	—	—
Residue, % [1]	24	32	95
Boiling point, ° C.	C.V.D.I.C.[2]	—	—
Molecular weight	510	300	458
Number of rings per mol.	1·0	0·45	1·65
Gain in rings in the experiment, %	−30	−58	0

[1] In the calculation of the quantities of the gaseous and liquid fractions (%) the total quantity of the raw materials augmented with the (small) weight of the hydrogen has been taken as 100%.

[2] Cathodic light Vacuum Distillation with Internal Condensation.

conditions were unfavourable for any marked secondary ring formation (see below), supporting the conclusion mentioned above.

3. *The primary reaction products (see 1 above) decompose very slowly with prolonged heating at 435° C.* Table III gives three comparable experiments differing only in the time of heating at 435° C. (Experiments 1, 2 and 3.)

TABLE III.

Number of the experiment.	1.	2.	3.	6.
Raw material and conditions of reaction.	B_2, Ni + H_2, 30 min.	B_2, Ni + H_2, 5 min.	B_2, Ni + H_2, 1 min.	B_2, Ni + N_2, 30 min.
First gas fraction, % [1]	15	16	17	18
Hydrogen in the gas, %	6	11	9	0
Unsaturated hydrocarbons, %	1	3	1	4
Mean number of C atoms per mol. in the paraffinic part	2·9	2·9	3·0	2·5
Second gas fraction, % [1]	10	16	6	5
Hydrogen in the gas, %	1	0	1	0
Unsaturated hydrocarbons, %	8	7	0·5	3
Mean number of C atoms per mol. in the paraffinic part	3·5	4·0	4·1	3·7
First liquid fraction, % [1]	18	20	15	18
Mean molecular weight	abt. 89	88	81	107
Number of rings per mol.	abt. 0	abt. 0	abt. 0	abt. 0
Second liquid fraction, % [1]	23	—	—	8
Mean molecular weight	142	—	—	—
Number of rings per mol.	0·2	—	—	—
Third liquid fraction (residue), % [1]	34	48	62	51
Mean molecular weight	282	253	235	241
Number of rings per mol.	1·05	0·5	0·2	1·5
Gain in rings during the experiment, %	−32	−60	−77	+60
Remarks	—	The distillation was stopped after removal of the first fraction.		The second liquid fraction was analysed together with the third one.

[1] See note 1 to Table II.

4. *The primary reaction (see 1 above) has the character of a "depolymerization."* By "depolymerization" is here meant a change in the cyclic character (and other physical properties) of the reaction products with the molecular weight similar to that observed in the polymerization of *iso*-butene, but in the opposite direction. In Fig. 1 the specific refractions of the completely saturated reaction products from experiments 7 and 8 (see also Table II) are indicated. The broken curve is that for the products obtained by polymerization of *iso*butene with aluminium chloride at room temperature. Both the experiments with high-pressure hydrogen without a catalyst and with nickel-on-kieselguhr as a hydrogenation catalyst give fractions corresponding with the broken curve.

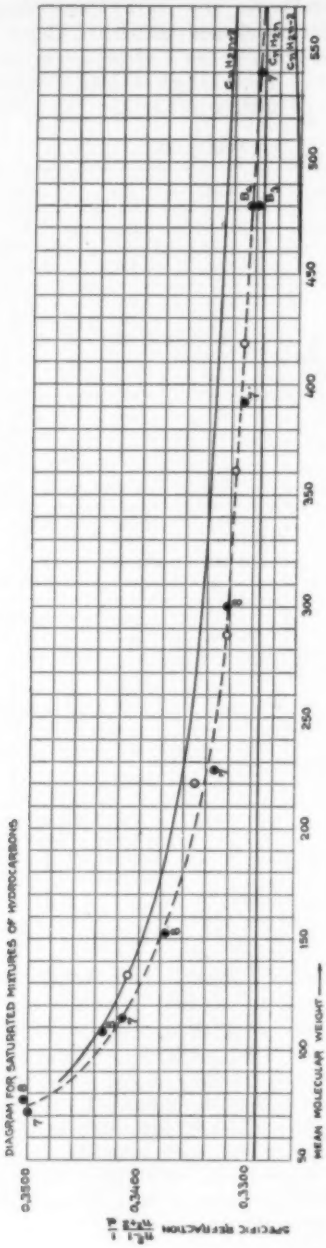
DIAGRAM FOR SATURATED MIXTURES OF HYDROCARBONS
SPECIFIC REFRACTION $\frac{n^2-1}{n^2+2}\frac{M}{d}$
0,3500
0,3400
0,3300
MEAN MOLECULAR WEIGHT
50
100
150
200
250
300
350
400
450
500
550
C_nH_{2n+2}
C_nH_{2n}
20-9-38

FIG. 1.

5. *When the primary reaction products (see 1 and 4 above) are heated further in the presence of nickel-on-kieselguhr, an influence of the hydrogenating conditions similar to that with Rangoon paraffin wax is observed.* In Table III an example is given of an experiment (Experiment 6) carried out under conditions which were most unfavourable for hydrogenation, and it may be seen that here, in the absence of hydrogen, the total number of rings increased to a marked degree. Figures are also given (Experiments 1, 2 and 3) supporting the conclusion mentioned above, since it is shown by the analysis of the gaseous products from Experiment 3 that even after the very short reaction time of 1 minute all the hydrogen had been taken up. Therefore the reaction conditions in Experiments 1 and 2 were unfavourable for hydrogenation. It will be observed that the loss of rings in Experiment 1 is smaller than that in Experiment 3. The results of Experiments 1 and 6 may be compared.

From the results obtained for the *cyclo*hexene polymers the following conclusions may be reached :—

1. *The* cyclo*hexene polymer mixtures investigated were much more stable under the reaction conditions already described than were the* isobutene *polymers.* The results of two experiments are given in more detail in Table IV.

TABLE IV.

Number of the experiment.	12	15
Raw material and conditions of reaction.	C_2, Ni + H_2, 60 min.	D_2, Ni + H_2, 60 min.
First gas fraction, % [1]	1	1
Hydrogen in the gas, %	10	79
Unsaturated hydrocarbons, %	0	0
Mean number of C atoms per mol. in the paraffinic part	1·5	1·3
Second gas fraction, % [1]	1	abt. 1
First liquid fraction, % [1]	11	7
Mean molecular weight	104	83
Estimated number of rings per mol.	abt. 1	abt. 0·4
Second liquid fraction, % [1]	3	—
Third liquid fraction (residue), % [1]	84	91
Mean molecular weight	242	202
Number of rings per mol.	3·0	2·5
Gain in rings during the experiment, %	+2	abt. −23
Remarks	The second liquid fraction was analysed together with the third fraction.	The distillation was stopped after removal of the first fraction.

[1] See note 1 to Table II.

2. *Comparison of these results with those already described* [4] *for two cyclic oils of natural origin and of about the same molecular weight showed that the differences in stability were not very great.* The natural products were somewhat more stable but the difference was small.

3. *No rings in the polymer fractions were destroyed under the reaction conditions unless they had been formed as extra rings during the polymerization.* This may also be illustrated by the two experiments given in Table IV. The cyclic character of the raw material C corresponded with the cyclic character of *cyclo*hexyl compounds of the same molecular weight, showing that ring formation had not occurred during polymerization. On the other hand, ring formation had occurred to some extent in the preparation of D. In all experiments the cyclic character of nearly all the reaction products corresponded with the cyclic character of *cyclo*hexyl compounds of the same molecular weight.

4. *Ring formation was never observed in the experiments even in those cases where hydrogenating conditions were most unfavourable—e.g.,* experiments under high pressure nitrogen in the presence of nickel-on-kieselguhr as catalyst.

Summary.

The rate of destruction at 435° C. of several synthetic hydrocarbon mixtures has been investigated under various conditions. The nature of the reaction products has been determined and the results have been compared with those for hydrocarbon mixtures of natural origin.

The conclusions reached are summarized in the paper in italics.

References.

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THE INSTITUTE OF PETROLEUM.

TWENTIETH ANNUAL DINNER.

THE Twentieth Annual Dinner of the Institute of Petroleum was held at Grosvenor House, Park Lane, London, W.1, on Monday, December 12th, 1938, Lieut.-Col. S. J. M. Auld, O.B.E., M.C., D.Sc., President, occupying the chair. About three hundred members and guests were present, including the following: The Rt. Hon. Lord Cadman, G.C.M.G., The Rt. Hon. Lord Stamp, G.C.B., G.B.E., The Rt. Hon. Sir Kingsley Wood, P.C., M.P., Sir Charles Bruce Gardner, Lt.-Col. J. H. M. Greenley, Prof. F. G. Donnan, C.B.E., F.R.S., General Sir Walter M. St. G. Kirke, K.C.B., C.M.G., D.S.O., Air Vice-Marshal W. L. Welsh, D.S.O., A.F.C.Eng., Vice-Admiral Sir George Preece, Major-General A. E. Davidson, D.S.O., Brig.-General Sir Harold Hartley, F.R.S., Air Vice-Marshal A. W. Tedder, C.B., Mr. J. B. Aug. Kessler, Mr. P. C. Kidner, Mr. C. B. Kingston, Dr. William Cullen, Mr. E. S. Shrapnell-Smith, C.B.E., Mr. F. C. Starling, Mr. H. B. Heath-Eves, Mr. A. L. McColl, Mr. R. W. Sellers, Mr. T. T. McCreath.

The loyal toasts, proposed by the President, having been honoured, The Rt. Hon. Lord Cadman, G.C.M.G., D.Sc., LL.D., D.Eng., proposed the toast of

"HIS MAJESTY'S GOVERNMENT."

LORD CADMAN said: I think we can all join in the toast of the health of His Majesty's Government with really sincere feelings. There have been, I think, few periods in our history when a healthy Government was more essential to the welfare of this country. The times are very difficult and the last really peaceful days which were enjoyed are long behind us. In the twenty-four years which have elapsed since their termination we have seen many changes and suffered many strains. First of all there was a long war out of which we emerged, as we then thought, victorious. The war was followed by a peace which we hoped was to be established for all time. Now we have a peace which is far from peaceful. Indeed, its principal feature is the intensity with which every nation is preparing itself for war.

In these circumstances, it is vital for our national security and existence that we should have skilled and able direction—a condition which is impossible unless we have a healthy State guided and controlled by a healthy Government. (Applause.) Fortunately, there are men in the present Government who have the qualities of vision, energy and drive which are vital to the conduct of great affairs in the stress of times such as these.

We are far from having forgotten the magnificent service which our Prime Minister rendered in averting war at a moment when everything seemed at its darkest. (Applause.) By that historic action he gained the admiration of the whole world. We owe Mr. Neville Chamberlain, and his Government, our heartfelt thanks for the wisdom he displayed in those anxious days of last September. There are thousands of people alive to-day who owe their lives to the Prime Minister's action.

A very large and important share in the task which the Government now has to perform is borne by our guest this evening—Sir Kingsley Wood. I have come into personal touch with Sir Kingsley in several of his political manifestations. On the first occasion he was Postmaster-General. The General Post Office was a fine organization even before Sir Kingsley Wood became its chief. It had, however, some defects, and it lacked the lubricant of harmonious co-operation with its millions of customers. After Sir Kingsley had taken it over there was a speedy and radical change. Bottlenecks were widened. Decentralization made for rapidity of decision. Mechanical operation and modern ideas in organization replaced many traditional but rather

cumbersome practices. Finally, a chilling austerity of manner was replaced by that geniality which always pervades the atmosphere around Sir Kingsley Wood. He put television on the map. It is a great thing for a Postmaster-General to be the first public officer in the world to introduce such a service to the community.

Sir Kingsley is now our Minister for Air. A few months ago, I had the privilege of an inside view of certain sections of the Air Ministry before Sir Kingsley took charge. From what I then saw I think that he on his arrival found much in common with the General Post Office as he first knew it—the organization was basically fine, but it had some serious defects. Sir Kingsley's period of office at the Air Ministry has, I know, already produced many good results. The confidence that is reposed in him is well indicated by the fact that criticism of his Ministry is stilled, and has been replaced by encouragement allied with expressions of trust.

The Air Ministry is a Department in which the petroleum industry has a particular interest. Each phase of our industry, of course, has its peculiar problems, and I would not rank any group above others in relative importance. There is, however, something spectacular about the air and aeroplanes which appeals to the imagination and raises their problems to an almost stratospheric eminence. In the solution of almost every problem of the air, engines and their fuel and lubrication are of fundamental importance.

It is in aeroplanes, for example, that the internal-combustion engine has reached a pitch of perfection and efficiency undreamed of in the early, and even in the latter, years of its development. This engine, moreover, like many other thoroughbreds, requires special forms of nourishment, and the provision of suitable fuels has not been accomplished without considerable effort. In the perfection of these products the Institute and all its members have rendered services which I am sure are fully appreciated by all.

Despite the high level which engines and fuels have already attained, I do not think that we in the petroleum industry are yet satisfied that the ultimate heights have been scaled. The internal-combustion engine might still be improved in matters of degree. For any revolutionary change, however, I think we must look elsewhere. My own hope is pinned to the development of an internal-combustion turbine using heavy fuel. This proposition is not new, and it bristles with difficulties. Nevertheless, there are indications that the essential problems of design which have hitherto proved insuperable are gradually being solved, and it may not be considered unreasonable to look forward to the oil turbine-driven aeroplane.

I hope, therefore, that at one of our future dinners we shall acclaim as the outstanding aeronautical event of the year the first flight of an aeroplane propelled by such an engine. Then, perhaps, the Air Minister and all connected with aviation will insist on drinking the health of those who contributed to its development. In the meantime, the duty is ours, and I have much pleasure in asking you to drink the health of His Majesty's Government, with special thanks to our Prime Minister, which I trust will be conveyed by Sir Kingsley Wood, whose name I couple with this toast. (Applause.)

The Rt. Hon. Sir Kingsley Wood, P.C., M.P., who responded, said: I thank my old friend Lord Cadman for the kind and generous way in which he has proposed this toast this evening. I was very much indebted to him when I was at the Post Office, when he largely helped to carry out the reorganization which we made in those days, and to-day I am very glad to say that he is a member of an important panel of business men who are helping us at the Air Ministry.

I am obliged also for his reference to the time when I occupied the position of Postmaster-General. We owe a great deal to the 230,000 odd men and women who conduct the affairs of the Post Office up and down the country, and I was very glad in those days in conjunction with them—and without them nothing could have been done—to try to help matters forward so far as the Post Office was concerned.

I am very glad to-night to respond to the toast of His Majesty's Government, and I think, if I may suggest it, that the petroleum industry and the Government have something in common. They have both sometimes been rather severely criticized, but both, I am glad to say, have managed to survive, and no serious rivals have as yet appeared to displace them. I think that the reason for that is that we both give good service, and that is why we prosper.

I thank Lord Cadman for his references to-night to the Prime Minister. Times indeed are difficult, but I should like you to feel that so far as the Government are concerned, despite disappointments and setbacks, we are determined to proceed with our policy of peace and appeasement. That policy can only fully succeed, of course, if there is the desire and the goodwill on the part of all countries, for peace can be permanently established not by one country, but only by many. I do not take the view, and I do not believe a single person in this room takes the view, that war is inevitable, and I would say to-night, speaking on behalf of the great majority of my fellow-countrymen, that we have not lost faith that common sense, goodwill and co-operation among the nations will yet prevail.

Lord Cadman referred to the Defence Forces of the country. I speak to-night in a very responsible position, one which I never sought, but which I am glad to occupy. Mr. Chamberlain the other day said that so far as the Defence Forces of this country were concerned, we must be so strong that the world may know that any efforts that we may make to promote peace are influenced not by fear of war, but by hatred of it. (Applause.) I think it is obvious that the more effectively prepared we are, the greater the part we shall play for peace in the councils of the nations.

I speak to-night—and I am very proud indeed to speak—for the Royal Air Force. I was glad to hear Mr. Churchill say the other day in the House of Commons that the Royal Air Force constituted one of the finest and most magnificent bodies of men and scientific attainments that exist to-day in the whole field of modern military progress. (Applause.) He has quite legitimately put forward his criticisms, but that is his testimony to the personnel of the Royal Air Force itself. I should like to testify to-night, from close association in the few short months for which I have been Secretary of State for Air with the Royal Air Force, that it is distinguished by courage, energy and capacity. One of the most gratifying things to me is that during the last few months very large numbers have joined that Force, and those young men who are coming forward in such great numbers to-day are distinguished by that same energy and capacity that belongs to the Royal Air Force itself.

I do not disguise for a moment that while much has been done in connection with our air defences, much remains to be done. It is the menace of the air, this new and sudden and powerful instrument, this modern means of assault, that is the main cause of uncertainty, unrest and dread in the world to-day, and it is for that reason that this country, not for the purposes of aggression, but in order that we may fulfil our international obligations and obtain security for ourselves, is steadily building up its air defences, such defences that it shall not be worth while for anyone to attack us. I suggest to you that that is what the country has a right to demand and a right to have. (Applause.)

I should like, in conclusion, to say a word to you about the special association of my Department with your own interests. I say "in conclusion" advisedly, because the other night I was at a dinner with my wife, and when I went home I said to her, "What did you think of my speech?"—a very dangerous question to put to her! (Laughter.) She said, "Well, I did not think you were quite up to your usual form. You did not take full advantage of your opportunities." I said to her, "What opportunities did I not take advantage of?" and she replied, "The opportunities of concluding your speech and sitting down." (Laughter.)

I should like to say, so far as my own Department is concerned, that our relations with the petrol companies continue to be friendly. (Laughter.) In fact, I may say that they are extremely amicable, and I desire to-night to acknowledge the keen interest that all the companies take in our many and most important problems of supply. If I may, on behalf of the Air Ministry, to-night, I should like to convey our best wishes to the Institute. I think you can be proud of it. It rightly maintains a high standard of qualification for its membership, and it certainly, from my point of view, makes a vital contribution to the nation, and it is doing much for the consumer of petroleum products. Although I am engaged in looking after our own country and its Air Force, the Institute has a special appeal to me because its membership is international, and I think rightly so, because there are no boundaries in research or in discovery. All our friends here to-night are associated with one of the youngest but one of the greatest of Nature's new forces, and I am glad to know that you are worthily taking your part in utilizing and directing it. (Applause.)

The Rt. Hon. Lord Stamp, G.C.B., G.B.E., Sc.D., LL.D., then proposed the toast of

"The Institute of Petroleum."

Lord Stamp said: I discern quite clearly that in the choice of the proposer of this important toast you have followed the now customary technique. He must be one who does not live too close to the works and see the spots, so that he can be relied on not to make a series of untimely criticisms at a convivial gathering, but at the same time he must be sufficiently near to appreciate all your virtues. Here, therefore, am I, with my wealth of ignorance and benevolence (laughter), ready to assure all of you that you really deserve all those good things that you constantly think about yourselves and occasionally in secret say to each other. (Laughter.) In order that I should not be completely lacking in equipment, I approached your Secretary, and, if I may use the proper terms, I find him in the matter of information to be a positive gusher. (Laughter.) In fact, for the first time I realized the meaning of the words "oil immersion." I do not know the hydrostatics of the subject; I do not know whether when you are drowned in oil you come up three times or not—I did not wait to see! (Laughter.) I do assure you, however, that the information which I had for quantity equalled that of a stores catalogue, and for quality was rather like an eighteenth-century mural epitaph. (Laughter.)

I had plenty of material, I can assure you, but when it came to compressing it into a speech of ten minutes' duration, that was another story, and I felt very much like the trench-digger recently in the crisis who, having dug a very fine trench, after the crisis was instructed by his boss to fill it in, which he duly did, only to find that he had a great deal of soil left over. He drew his boss's attention to it, and his boss said, "I told you all along, you silly fool, that you were not digging it deep enough." (Laughter.) I assure you that I had a great deal of material left over, and I think it was not because I was not digging deep enough; but I do know now enough about your claims to public notice and respect to propose this toast with great heartiness and conviction.

I notice that your life as an Institute coincides almost with the period of astonishing growth of production in petroleum products, which has been going on since 1913, quadrupling in the last few years. In some senses 1913 was a turning-point, a new order of magnitude and a difference of degree became almost a difference of kind. You have had the inestimable advantage as an Institute of gradually growing up with your subject. I am not going to say which was cause and which was effect (laughter), whether this marvellous increase in the production of oil is due to you or in spite of you, but, quite rightly, you were first of all devoted to the extraordinarily rapid growth of technical processes and refinements of them and innovations, but as time has gone on you are being drawn into the increasing, not specialization, but generalization of the interest in your profession, and its effects upon society. You have now gone into the field of education with the promotion of scholarships. You have not yet reached the stage of an entrance examination, but I expect that, like the other budding institutes, you will do so in order to submit would-be new entrants to an examination which you yourselves never passed and never could pass. (Laughter and applause.) "Yes, my boy, but you see I was a pioneer!" (Laughter.)

I think you have been very fortunate in your change of name, because it does now indicate the existence of a wider forum for discussion of those general questions to which I have referred, and in your new home, and with this now recognized width and breadth of view, you are beginning in your twenty-fifth year a fresh stage of your usefulness to society. You have accomplished a very great deal which is of extraordinary value to the industry and to the industries dependent on you. The standardization of methods of testing and the voluminous literature which you now produce, which seems to me quite concise and not unduly watered or oiled, but really thoroughly scientific in its compactness and directness, the reviews that you produce, these three or four encyclopædic volumes covering every range of your subject—all these things show the intellectual aliveness of your Institute. The promotion of the branches abroad brings out strikingly the international character of your efforts, and the fact that half your members are overseas shows that you are one of those forces—and we want all we can get to-day—which bind nations together in unity of purpose and of knowledge. (Applause.)

It is expected of me that I should say something of the economics of petroleum, but I can assure you that I am going to spare you. Not long ago I was at a wedding breakfast, and was just about to propose the toast of the bride and bridegroom when someone pushed across a note to me. I opened it and found that it said "None of your blooming statistics!" (Laughter.) The extraordinary thing about the economics of your subject is that there are not any economics; there are only statistics; because almost every economic test or criterion that you can apply is either defeated or lacking. (Laughter.) For example, you can find no rational connection between the aggregate supply in your industry and the particular price that rules at the time. (Laughter.) Apparently at no time has it really been dependent on demand; it has been entirely unpredictable, and largely due to the fortuitous occurrence of new fields which have been discovered, and the development of new drilling conditions, and even the decline of the older fields, and these things have gone on sweetly and blithely unconscious of the uses that were made of your product or of the particular price which happens to have been ruling, and only to a minor extent have the fluctuations been dependent on consumption or the movement of prices.

Demand seems to have paid very little attention to the supply or the price. The economic growth of all kinds of new uses, the internal-combustion engine, aviation and a hundred other different uses of your product, direct or derived, has ruined any ordinary economic demand schedule, and when you look at the price, you find that, far from being a mere equation between demand and supply, it has been in various countries tremendously dependent upon taxation, which has sometimes far exceeded the cost of your product. Your industry follows no economic rule, and when it comes to the question of co-operation for the control of supply and the regularization of price, in the case of the U.S.A., by far the largest producer, we know that only for a short time has that been a feasible and practicable proposal followed out logically. For a long time, indeed, it was forbidden. It is rather interesting to remember that the Shearman anti-trust laws had their origin very largely in the efforts of a number of oil producers to put a check to the activities of the Standard Oil Company. Now the wheel has gone full circle. I remember commenting on the fact, soon after N.R.A. began, that the Shearman anti-trust laws had never been repealed, but only overlaid by a new set of instructions from Washington. Producers in this as in other industries had for a generation been told that they must never be seen in each other's company, or they would be suspected of discussing prices and output, or doing something to make a disorderly industry into an orderly one. That was a fatal thing to do. Suddenly, however, from Washington came the announcement that these were the things which had to be done, and that if they were not done it would be disobeying N.R.A., and all the punishments of the law would fall upon them. If, however, the N.R.A. decrees were ineffective, presumably the Shearman anti-trust laws would be invoked, and that, in fact, is exactly what happened. A very large number of oil producers did get together and do something of the kind which these N.R.A. orders required, and when the orders were declared to be unconstitutional, Washington proceeded in the courts of law against these various people under the old Shearman anti-trust laws, and they had a difficult time trying to justify themselves for going in two directions at once. (Laughter.)

I have said that you have now a forum for the widest discussion of your problems, and indeed your problems are wide because now oil and its interests have penetrated far beyond technical processes, far beyond immediate uses, and have become a part of the politics and of the international complications of the world. I suppose recent events might have been different, or at any rate qualified, if the League of Nations had retained authority. The League of Nations might have retained authority if its policy of sanctions had been successful. It is quite possible that its policy of sanctions might have had a very different history if the policy of oil sanctions in particular had been effective. (Applause.) When you get down to it, you will find that the position of oil and the demand for it are becoming a first-class underlying problem in almost every political question. We do not even now know the extent to which war will be modified by the dependence of nations upon oil, but we can see that it will be a tremendous factor—the power to obtain it in sufficient quantities to maintain a highly mechanised Army, Navy and Air Force.

Not only is it getting into economic politics, but it is also getting into such economic questions as foreign investment. We all know the enormous number of restrictions

that dissuade us from foreign investment to-day, but I suppose that no single thing has come as such a shock to the possibilities of foreign investment as the recent repudiations of the Mexican Government and their action over Mexican oil. Whether right or wrong, explainable or excusable, is beside the mark; it is the general effect on the mind of foreign investors throughout the world which is one of the major factors in the field of foreign investment. You cannot in this forum of your Institute ask any question which will turn out in its effect to be like the question asked recently in the courts by a barrister, who said to the witness: "You say that at one o'clock you called on Mrs. Murphy. What did she tell you that Mr. Jones said?" Counsel on the other side got up and said "I object to the question," and there ensued a long wrangle, and for an hour or two the two opposing counsel and the judge discussed whether this particular question was permissible in the circumstances. Finally the judge ruled that it was, and so once again counsel addressed himself to the witness and said, "You say you called on Mrs. Murphy at one o'clock. Now what did she tell you Mr. Jones said?" The answer was "Nothing; she was not in." (Laughter.) Many scientific societies bother themselves with questions only to find that when they have been settled nothing happens, and you are entitled to ejaculate the American slogan "So what?" In your own case I am quite sure that every question that can be asked relating to oil will have some definite bearing, so wide, so important and so far-reaching are many of the consequences.

If praise is to be given, I believe you deserve it, and at any rate you think that you do. (Laughter.) I did take the precaution of consulting one or two people before I came who I thought might know something about you, and on all hands I had such a certificate of respectability for you as almost made me suspicious. It was very different from my experience last week, when I was going to speak for the guests at quite a different function from this, and I saw somebody who said "Where are you going to speak?", and when I told him he said "Oh, that lot! Are you casting any pearls?" (Laughter.) That brought to my mind a certain lady with two daughters, who were ageing a little, still on her hands, and she put it in these words:—

"I have two girls, a couple of pearls,
And what should I ask for more?
But I see no sign of a couple of swine
To cast those pearls before." (Laughter.)

If I may speak for your guests in presenting our thanks, I should like to say that you have given us a royal time. I have been told by the President that technical efficiency in your industry is so far advanced that such a thing as a blow-out is now considered rather a disgrace. (Laughter.) I feel, however, that it is what you have given us to-night. At any rate, I, who have been clamouring for a week or more for a square deal, have certainly had a square meal to-night. (Laughter.)

It is my duty and my pleasure to couple with this toast the name of the President of the Institute, Colonel Auld. I know that in him your interests are in safe hands, and I know that many of those progressive movements to which I have been referring have behind them his dynamic personality and that he has invigorated your interest, and I am sure will continue to do so. I ask you to drink to the health of your Institute and of your President, Colonel Auld. (Prolonged applause.)

Lieut.-Col. S. J. M. Auld, O.B.E., M.C., D.Sc., who was received with applause on rising to respond, said: Like everyone else, I suppose, there are times when I feel not entirely adequate to the task in hand, and this is one of them. I am very proud, as Sir Kingsley Wood suggested I should be, of the Institute of Petroleum, and I am proud to be answering for it to-night, and that makes my sense of unworthiness a little greater. In addition to that, I have to reply to Lord Stamp, of whom I stand in a great deal of awe. (Laughter.) Lord Stamp has done us a great honour by coming here to-night. That this great economist, this celebrated man of affairs, should have come here to propose the toast of the Institute of Petroleum is very much appreciated. (Applause.) I cannot possibly hope to match his wisdom, his forthrightness and the generosity of his good wishes except by the sincerity of my thanks and my sincere admiration for himself. The natural respect which I have for Lord Stamp as the President of the L.M.S. Railway is intensified by the great deference which I have for all great railwaymen. This is, I think, almost a true infantile fixation as far as I am concerned, because

I was almost literally cradled on the old Glasgow and South-Western Railway, and I stood in very great awe of the engine-drivers; in fact, one of my earliest recollections is of escaping from surveillance in company with another toddler and putting pins on the railway line to see how beautifully they were flattened out by the trains. That amusement went on with increased daring until we were chased away by the drivers throwing coal at us. (Laughter.) Cause and effect, you see! You stick pins in the railways and eventually they throw things at you. (Laughter.) They have had to put up with a good many pins in the last few years, and now they are beginning to throw the coal. I think most of us will wish them the greatest success in the fight which they are now making for their square deal. (Applause.)

It is my privilege as President to be somewhat incidental in my remarks, and to refer briefly to the major happenings of the last twelve months of the Institute's life. Following the lead of Lord Stamp, I shall endeavour, however, to spare you all figures. All figures, that is to say, except perhaps figures of speech, because, in thinking over the things that I wished to refer to, I found that they had an uncommon resemblance to the happenings of a year of matrimonial bliss. They started out with the wedding, then the honeymoon, the new home, the house-warming, and then the facing of the battle of life. I refer, of course, to our change of name and constitution, to our trip to Scotland this year for our Summer Meeting in the form of a Conference on Oil Shale, to the occupation of our new premises, to the very successful Conversazione which we recently held, and then to the Crisis. Let us hope that we may add to the whole lot the living happy ever afterwards. (Laughter and applause.)

Our change of name from the Institution of Petroleum Technologists to the Institute of Petroleum in itself explains fully the broader path which we are now following. We have, as I have previously explained, taken very great care to safeguard the interests of our technial purists, but we realize, as I have heard it said elsewhere, that it is possible to be "too sanguinary pure." (Laughter.) I can assure you that that was not the intention of the founders of the Institution nor of those responsible for its emergence as the Institute.

One of the first evidences of our new outlook has been the formation of separate groups to take care of and encourage the interchange of thought about special subjects. The first two of these groups have been the Lubrication Group and the Asphaltic Bitumen Group. But I should like in the presence of Lord Stamp and Mr. August Kessler to plead for the formation of an Economics Group, and in the presence of Mr. Heath Eves and Mr. McColl to plead for the formation of a Distribution and Marketing Group. There in a nutshell and in type are our aims and aspirations, but we cannot do these things until we have the right type of member. I would point out to you that Mr. Kessler, for example, who has always been the staunchest supporter of the Institute in the past, is not a member, and that Mr. Heath-Eves is not a member, and that Mr. Alex McColl is not a member. (Cries of "Shame.") They might and would have said in the past, "We are not technical men; how can we be members?" At any rate, they can now be members, and it is not merely that they can, but that they ought. We ask them, and we ask all the administrators of the oil companies, to join us in this new and great venture, and to bring with them their colleagues, and particularly amongst their colleagues their brightest young men and their bluest-eyed boys. (Laughter.) The primary qualification that we shall demand in each case before we do anything else is that a man shall be able to say, "I am an oil man."

The Institute has already three very lusty offspring. Two of them are the groups which I have mentioned, but the first was the Scottish Branch, of the existence of which we are very proud. The Scottish Branch was the immediate result of the holding of the conference on oil shale at the Empire Exhibition in Glasgow this summer. This very precocious infant did not exactly appear with a silver spoon in its mouth, but it appeared with a very weighty tome in its hand, the volume to which I refer being the record of the conference. This book is unique; there is no other record of its kind in existence as far as I know, and we are naturally proud of it. I am not bringing it to your special attention, however, because of its intrinsic value, but because it is, as I see it, a symbol of all the publications of the Institute of Petroleum; it is a symbol of all the work which has been done and which is being done by the Institute on behalf of the industry, and it is a symbol of all the work which the Institute will continue to do for the industry on an ever-widening front.

What in return is the petroleum industry doing for the Institute? It does, in fact,

a great deal. It liberates its servants to work for the Institute—almost uncomplainingly. (Laughter.) It, perhaps in a rather grandmotherly way, encourages them to attend meetings and write papers. The industry, in fact, is very friendly disposed towards the Institute; but that is not the whole story. Well-wishing is not all. Twice in the twenty-five years of our existence the industry has come forward with financial help in the matter of premises. The second occasion is quite recent, and is due to the activity of my very distinguished immediate predecessor in office, Lord Cadman. (Applause.) Lord Cadman felt—and, being Lord Cadman, had no hesitation in saying—that a *passé* fourth-floor-back was no fit headquarters for a body such as this, which had so helped to build a new industry, and an industry of this magnitude and richness. As a result, a number of groups came forward and offered to help us financially in such a way that we should not be hindered in our present endeavours towards expansion. By their aid we were able to take on quite commodious and very dignified premises in the beautiful new Adelphi building. I should like to take this opportunity of thanking most sincerely the bodies who were responsible. (Applause.) My gratitude, however, must not be looked on in a cynical way as a sense of favours to come when I point out that that position must be temporary. The industry as a whole must awake to its responsibilities to the Institute. It is not always realized that this Institute, not very old as many such bodies go, but very powerful, has been kept going, and is at present kept going, almost wholly by the subscriptions of men whose average salary is probably less than half of one day's cost of advertising to one of the major distributing companies.

Surely that is wrong. As an Institute we deserve, and we intend eventually to obtain, our own permanent premises. We want to embark upon ever greater standardization work. We want to develop our *Journal*. We want to increase our educational efforts. We want, in fact, to be, and we intend to be, an Institute worthy of the great industry to which we are all proud to belong. These things cost money. We want money, and we want it without any possible strings attached to it. I feel that we must form a building and endowment fund, and then it will be the privilege of the industry to contribute to that fund as a tribute to the work which I claim that the Institute has done, and continues to do, for the industry. With that, and with the greatly increased membership to which we look forward under these new conditions, I am convinced that the work which we shall do in the future will be even greater than that which we have done in the past.

You will realize that, rather contrary to the accepted tenets of good behaviour, I have somewhat sermonized and talked at many of our good friends among the very distinguished guests whom we have with us to-night. I am sure, however, that they will forgive me. In any case, I think that sometimes we are just a little too formally polite even to our guests. (Laughter.) I think in that connection of the young man I have heard of whose father had placed him in a whole succession of jobs in departmental stores as a salesman, and from each of them the boy was sacked. His father was very disturbed about this, and demanded to know what he could possibly do with him. "Father," said the young man, "I want to be policeman; I think I could do better in a job where the customer is always wrong." (Laughter.)

To complete my simile I would refer again in passing to the very successful conversazione which we held quite recently in the house of the Royal Geographical Society, and conclude with a few words about the very last stage—the facing of the battle of life; in other words, the Crisis, which naturally formed the basis of that very stimulating speech by Sir Kingsley Wood. At the time of the crisis as a matter of course I placed, through the Petroleum Department, the whole resources, collective and individual, of the Institute unreservedly at the disposal of His Majesty's Government; but it occurred to me then, and it has occurred to me with a certain amount of force since, that perhaps there is still something which might be done during the period of preparation. It is not possible always to get in touch with the people whom you want to be in touch with, and I am wondering whether the greatest use is made by the Government of the very highly organized scientific and technical professional societies, like our own. The Government Departments are only too willing to send their representatives to our committees—to our standardization committees, for example—but it might be that something could be done by their asking us for direct representation on their own committees in matters either directly or indirectly connected with petroleum—speaking, as I can, only for our own Institute. There are several cases within my

personal knowledge in this great matter of preparation where an improvement could unquestionably have been brought about by that method. At any rate it would be better than the somewhat haphazard, however intimate, contacting which goes on at present. Experience is that whilst individual companies or it may be individuals or groups of individuals, are in the closest touch with the Services and the Government Departments, the Institute as such is not. Moreover this method of keeping in touch is very frequently shrouded in quite unnecessary mystery—in what I might refer to as a mist of occultation. (Applause.)

It might be felt that representation such as I am suggesting might be capable of being misused for personal or commercial ends, but I can assure you that that is not the case. A man who represents his society as a delegate is a very different man from one going on his own business or that of his company. Mr. Shrapnell-Smith, I am sure, will bear me out on that point.

In the presence of so many eminent Fellows of the Royal Society, I do not wish to be construed as wanting in any way to intrude on their established privilege of acting as advisers in scientific matters to His Majesty's Government. It is rather that through specialist organizations like our own it would be possible to concentrate for the benefit of the community accumulated knowledge and experience not otherwise available. Moreover, at the back of individual representatives it must be remembered that there would be whole teams of men only too willing and anxious to discuss and to advise and, if necessary, to embark upon teamwork investigation—I will not even claim to call it research—for the elucidation of particular problems which may occur. Such matters as these are very much in all our minds, I know, and I think up and down the country it is a sure sign that we are awake, and that we now know that what Swinburne said a good many years ago is true, that it may be better to weep than to slumber.

I will conclude, Lord Stamp, by thanking you again very heartily for your kind words, and by assuring you that the Institute of Petroleum will not fail to give of its best on behalf of science and in the service of the petroleum industry and of the Country. (Applause.)

I should mention that two messages of greeting have been received, one from the Trinidad Branch and the other from our good friend Colonel Pineau, Director of the Office Nationale des Combustible Liquides. (Applause.)

The proceedings then terminated.